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IMPRIMERIE BIANCO LUNO

On the Determination of pH in Seawater at Different Temperatures.

By

K. Buch,

Thalassological Institute, Helsingfors.

In determining the *pH* of sea-water, sufficient regard has hitherto not been paid to the influence exercised by temperature.

As a rule, the temperature factor has been ignored entirely; in certain special investigations corrections have been made in a few instances, having been obtained by colorimetric determination of the changes in colour undergone by buffer indicator solutions during temperature changes.

If determinations are carried out — as at present is almost invariably the case — by the indicator method, the influence of temperature is of rather a complex character. Both buffer solutions, where such are used, and the fluid under examination may change their indicator colour with changes of temperature, but such changes of colour need not necessarily be in the same direction. If, for example, a sample of seawater and a borax buffer solution at a low temperature receive an admixture of phenol red and are afterwards heated, it will be found that the colour of the buffer changes in an alkaline direction, while that of the water has changed in an acid direction. But whether and to what extent *pH* changes have taken place in the respective solutions it is impossible for us to judge. Borax buffer solutions, with an admixture of cresol red, even show, as described later, the peculiarity that the colour of an alkaline mixture (*pH* about 8.5) fades with rising temperatures, whereas that of an acid mixture ($pH = 7$) is intensified. Between these limits, at about $pH = 8.20$ the colour remains perfectly unchanged. During the seasonal expeditions it may happen that samples of water taken from different depths at one and the same position, show differences in temperature of up to 25° C. It is obvious that if these samples are colorimetrically determined by one and the same buffer at a constant temperature, the values obtained cannot be exactly comparable with

each other. A quantitative investigation of the temperature error must embrace every factor in regard to which temperature plays a rôle. Such an investigation has been carried out by the author and described in an earlier work[1]). This consisted of spectrophotometric investigation of the absorption of light by different colour indicators in buffer solutions and in sea-water of varying temperatures. This question was dealt with theoretically on the assumption that the indicators examined are weak acids, which become ionized on the addition of a base. The ion differs in colour from the undissociated acid. By applying the mass action law, it is possible to deduce a simple formula for calculation of the *pH* of the water at the time of collection, if once the temperature at that moment, as well as the *pH* and the temperature of the standard buffer solution with which the water sample has shown itself identical in colour on colorimetric determination, be known. If the two latter temperatures are indicated by t_w and t_b respectively, the *pH* of the comparison standard at the temperature t_b by pH_{t_b}, and that of the water by pH_{t_w}, one arrives at the *pH* of the water by means of the equation

$$pH_{t_w} = pH_{t_b} + \alpha\,(t_w - t_b)$$

α is a constant, individual for each indicator, showing the amount by which the dissociation exponent of the indicator varies for a temperature change of one degree. If the sample of water and the buffer solution used are of identical temperature, as is almost always the case in laboratory research, the term $\alpha\,(t_w - t_b)$ falls away, and the water should be allotted the same *pH* as that possessed by the buffer solution at the prevailing temperature. Should the latter deviate greatly from the temperature at which the *pH* of the buffer series has been fixed (generally 18° C.) a correction has to be made. WALBUM's[2]) investigations on the *pH* of a number of S. P. L. SÖRENSEN's standard buffer solutions have been of utmost value for fixing such a correction. The solutions used in the examination of sea-water are SÖRENSEN's phosphate solutions and especially PALITZSCH's[3]) boric acid-borax

[1]) KURT BUCH: Über den Einfluss der Temperatur auf die *pH*-Bestimmung des Meerwassers; Merentutkimuslaitoksen julkaisu Havsforskningsinstitutets skrift N:o 61. Helsinki (Helsingfors) 1929.

[2]) WALBUM, L. E. Über die Wasserstoffionenkonzentration einiger Standardlösungen bei verschiedenen Temperaturen; Biochem. Ztschr. *107*, 219. 1920. Ref.: W. MANSFIELD CLARK: The Determination of Hydrogen Ions. Third Edition, Baltimore 1928. Page 209.

[3]) SVEN PALITZSCH: Om Anvendelsen af Boraks- og Borsyreopløsninger ved den kolorimetriske Maaling af Havvandets Brintionkoncentration. Meddelelser fra Carlsberg Laboratoriet 11te Bd. 5te Hefte 1916. Ref. CLARK's manual, page 213. Se foot note [2]).

mixtures. According to WALBUM the *pH* of the former do not alter with the temperature. The latter have not been examined, but one has valid grounds for assuming that their sensitiveness to temperature will be similar to that of SÖRENSEN's borate + HCl solutions, which were investigated by WALBUM. By the aid of WALBUM's last-mentioned measurements, the author has made up an interpolation table (Table 1), showing

Table 1.

	pH	Temp. Coeff.	$t=10°$	$t=12°$	$t=14°$	$t=16°$	$t=18°$	$t=20°$	$t=22°$	$t=24°$	$t=26°$	$t=28°$	$t=30°$
Extrapolated	6.7	0.0021	+0.02	+0.01	+0.01	±0.00	±0.00	±0.00	—0.01	—0.01	—0.02	—0.02	—0.03
	6.8	21	2	1	1	0	0	0	1	1	2	2	3
	6.9	22	2	1	1	0	0	0	1	1	2	2	3
	7.0	22	2	1	1	0	0	0	1	1	2	2	3
	7.1	23	2	1	1	0	0	0	1	1	2	2	3
	7.2	24	2	1	1	0	0	0	1	1	2	2	3
	7.3	25	2	1	1	0	0	0	1	1	2	2	3
	7.4	27	2	2	1	+0.01	0	—0.01	1	2	2	3	3
	7.5	28	2	2	1	1	0	1	1	2	2	3	3
Interpolated	7.6	30	2	2	1	1	0	1	1	2	2	3	4
	7.7	31	2	2	1	1	0	1	1	2	2	3	4
	7.8	33	3	2	1	1	0	1	1	2	3	3	4
	7.9	35	3	2	1	1	0	1	1	2	3	3	4
	8.0	37	3	2	1	1	0	1	1	2	3	4	4
	8.1	39	3	2	2	1	0	1	2	2	3	4	5
	8.2	42	3	3	2	1	0	1	2	3	3	4	5
	8.3	45	4	3	2	1	0	1	2	3	4	5	5
	8.4	48	4	3	2	1	0	1	2	3	4	5	6
	8.5	50	4	3	2	1	0	1	2	3	4	5	6
	8.6	54	4	3	2	1	0	1	2	3	4	5	6
	8.7	58	5	3	2	1	0	1	2	3	5	6	7
	8.8	62	5	4	2	1	0	1	2	4	5	6	7
	8.9	66	5	4	3	1	0	1	3	4	5	7	8
	9.0	70	6	4	3	1	0	1	3	4	6	7	8

by how many *pH* units the inscription on the buffer solution container, referring to a temperature of 18° C., will need to be corrected to indicate the *pH* at the actual temperature of the buffer. The lowest temperature shown in the table is 10° C., which was the lowest limit of WALBUM's temperature investigations. Extrapolation below this temperature cannot be considered advisable, as WALBUM himself had already made use of an extrapolated value for a constant needed in the calculations for

the electrometric determination at 10° C. Furthermore, the *pH*-range of the borate + HCl buffers investigated by WALBUM does not exactly coincide with PALITZSCH's boric acid-borax series, so that extrapolation was already partly necessary when calculating the temperature correction in the latter series. However, this extrapolated range of the borax series will but seldom come into question as far as ocean-water is concerned.

The necessity of observing the second term $\alpha (t_w - t_p)$ obviously depends on the value of α and the difference in temperature between the sample of water and the buffer[1]). In the indicators examined by the author, α varies between the values 0.010 and 0.005, so that, with a difference of 20° C. between water and buffer, we may reach an error of up to 0.20 *pH*-units, i.e. a value considerably in excess of the usual run of experimental errors. The experiments should consequently be carried out so as to have the smallest possible difference $t_w - t_b$. This is, however, possible only to a very limited extent. We have already pointed out above, that the comparison series should not go below 10° C. ATKINS[2]) among others, has proposed that water of low temperature should not be measured immediately, but that the sample water should first be brought to approximately the same temperature as that of the buffer mixtures. This is, however, not altogether advisable, since equilibrium may be disturbed by the loss of carbonic acid (which is, however, of minor importance as regards sea-water and can be avoided by taking suitable precautions)[3]), and further the indicator colouring of the water may change considerably with the temperature, as pointed out in the aforementioned work of the author, and as will also appear from the investigations here described. It is desirable, on the contrary, that the temperature of the water when measured should approximate as nearly as possible, to the temperature at the moment of collection. Should there be even some slight deviation, the original temperature of the water *in situ* ought to be assigned as the value for t_w in calculation.

The use of the aforementioned equation postulates satisfactory knowledge of the temperature coefficient of the dissociation constant

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[1]) Even in those instances where measurements are made by means of a colorimetric apparatus, so that comparison buffers are unnecessary, the influence of temperature on the buffers can nevertheless not be disregarded. The pH scale of the apparatus is generally calibrated with a buffer series at 18° C. and the calculation must then be worked as if this buffer had been used and its temperature were 18° C.

[2]) W. R. G. ATKINS: The Hydrogen Ion Concentration of Sea Water etc. Part II: Journ. Marine Biol. Assoc. Vol. XIII No. 1. 1923. Page 94.

[3]) See K. BUCH: Die *pH*-Bestimmung des Meerwassers etc.; Merentutkimuslaitoksen julkaisu Havsforskningsinstitutets skrift N:o 53. 1928. Page 22.

of the indicator used in measuring. By means of a series of spectrophotometric measurements at different temperatures this coefficient has previously been determined by the author as regards the indicators — α-naphtholphthalein, phenolphthalein and phenol red, which are all used in sea-water investigations, especially for water of low salinity. In examining ocean-water o-cresol-sulfon-phthalein or cresol red has now come into general use, and consequently this indicator has also been made the subject of a similar investigation, the results arrived at being described more particularly below. The investigation comprises 1) Spectrophotometric measurement of the absorption of light by cresol red in both alkaline and acid mixtures with varying wave-lengths, whereby the absorption spectrum of the indicator has been determined, together with the optimal wave-length for the following *pH* investigations. 2) Spectrophotometric measurement of the absorption of light of a series of boric acid-borax solutions mixed with cresol red at room temperature, whence the indicator's transformation curve and dissociation exponent have been calculated for 18° C. 3) Spectrophotometric investigation of some buffer solutions, and variations of their temperature, whence the temperature coefficient of the dissociation exponent has been calculated. 4) Spectrophotometric determination of sea-water, with an admixture of cresol red, at varying temperatures, rendering it possible to determine the extent to which the *pH* of the water is influenced by temperature.

1. Determination of the Absorption Spectrum of Cresol red.

A sample of cresol red from Schering-Kahlbaum A.-G., Berlin, was at first used in a 0.04 % alcoholic solution as a stock solution. Afterwards it was found that the indicator treated in this manner did not keep well. Spectrophotometric control determinations showed that after a few days had elapsed the colour strength had already faded several units per cent. After various measurements had been rejected for this reason, a preparation of the same strength dissolved in water, with the addition of NaOH in the proportion given in Clark's manual[1]) was used in later experiments with buffer solutions and has proved to keep well. For purposes of spectrophotometric determination 1 cm³ of this solution was added to 50 cm³ of the fluid under examination. This strength, (0.008 g/l), was afterwards used for all indicator investigations. The absorption spectrum of the indicator was fixed both in acid 0.001*n*

[1]) 3 Ed. Page 94.

HCl and in basic 0.001*n* NaOH solution. For spectrophotometric determination a KÖNIG-MARTENS spectrophotometer, supplied by Schmidt & Haensch[1]), Berlin, was used. The measurements were always carried out with the light passing simultaneously through two parallel solution tubes of equal length, the one tube containing the fluid under examination + indicator, the other the same fluid with no admixture of indicator, thus eliminating the light absorption of the fluid under examination. Fig. 1 below and Table 2 show the results of these investigations. The absorption of light is shown as the extinction coefficient ε, defined by the equation

$$\frac{J'}{J} = 10^{-\varepsilon d}$$

in which J is the quantity of light entering the fluid, J' the quantity penetrating through it and d the thickness of the layer penetrated.

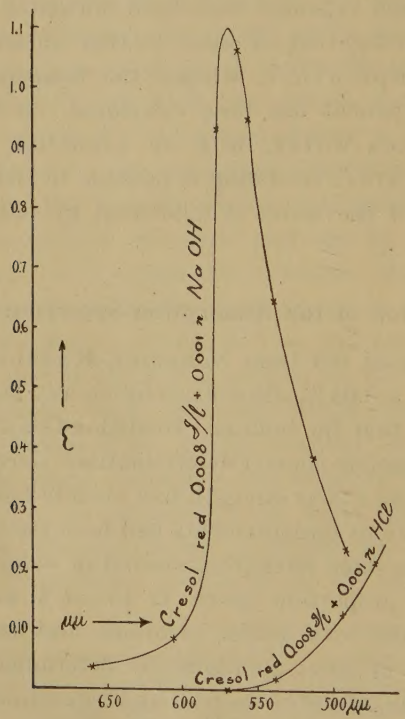


Fig. 1.

[1]) F. F. MARTENS und F. GRÜNBAUM: Ueber eine Neukonstruktion des Königschen Spektralphotometers. Ann. d. Phys. (4) 12 pp. 984—1003 (1903).

Table 2.

Wave length $\mu\mu$	Extinct coeff. ε	Wave length $\mu\mu$	Extinct coeff. ε
0.001 n NaOH		0.001 n NaOH	
660	0.032	513	0.387
604.5	0.084	492	0.238
577.5	0.929	0.001 n HCl	
570	1.078	570	0.0025
	1.097	539	0.0169
	1.108	513	0.0721
563.5	1.060	492	0.1311
557	0.946	474	0.2154
539	0.643	—	—

The maximum absorption of the indicator is found at the wave-length 570 $\mu\mu$. All later measurements of buffer solutions and sea-waters were made solely at this wave-length. The mean value of absorption at this wave-length was 1.094, which was used in calculating the indicator's dissociation constant. We may further point out that the absorption of the indicator in an acid solution at the same wave-length is practically 0, so that all absorption values mentioned hereafter are derived solely from the indicator ion, the application of BEER's law rendering it possible to calculate the concentration of the latter directly from the absorption.

2. Cresol red and Boric acid-borax Buffer Solutions at room temperature.

In order to obtain suitable boric acid-borax buffer mixtures recourse was had to PALITZSCH's[1]) boric acid-borax solutions, which were mixed so that the solutions received the pH values valid at 18° C., given in Table 2, col. 1. Col. 2 indicates the temperature at which the measurements were carried out. Col. 3 shows the extinction values arrived at, col. 4 the value of the dissociation exponent pK (the negative logarithm of the dissociation constant), which was calculated by the application of the mass action law to the transformation equilibrium of the indicator by means of the equation

[1]) SVEN PALITZSCH: Om Anvendelsen af Boraks- og Borsyreopløsninger ved den kolorimetriske Maaling af Havvandets Brintionkoncentration. Meddelelser fra Carlsberg Laboratoriet 11te Bd. 5te Hefte, 1916. S. 193.

$$pH - \text{Log}\,\frac{\varepsilon}{1.094-\varepsilon} = pK$$

thus making use of the fact that the absorption coefficient ε can be regarded as a directly proportional to the concentration of the indicator ion.

Table 3.

N:o	1 Boric acid-borax buffer. pH at 18°	2 $t°$	3 Extinct. coeff. 770 $\mu\mu$	4 pK
1	6.80	19.0	0.049	8.13
2	7.15	21.0	0.106	8.12
3	7.45	17.4	0.195	8.11
4	7.75	21.0	0.332	8.11
5	8.05	19.0	0.495	8.13
6	8.35	21.0	0.679	8.14
7	8.65	19.5	0.838	8.13
8	9.24	19.0	1.016	(7.32)

Mean (1—7): 8.124.

The results of the different measurements show a satisfactory coincidence, except in the case of the most alkaline buffer. This result coincides with the results of earlier investigations of other colour indicators, which correspond with the theoretic course only as far as the linear part of the transformation curve is concerned. A theoretic transformation curve, calculated in the reverse manner from the pK-value 8.124 and the absorption value in alkaline solution 1.094, coincides in the pH range — within which the indicator can be used — almost completely with a curve drawn through the experimental points. In CLARK's[1]) manual, we find for the same indicator $pK = 8.3$, but it is not stated with the aid of which buffer series this determination has been made. The value of the constant varies with the quality and character of the electrolyte. A graphic representation of the course of the transformation of the indicator will be found in fig. 2 (right of figure, curve at 20° C.). The curve has been slightly corrected, so as to correspond exactly to the temperature indicated.

[1]) 3 Ed. Tabl. 23. P. 102.

3. Cresol red + borax Buffers at varying Temperatures.

The measurements at other than room temperature were made by the spectrophotometer tube, already filled with the fluid under examination, being placed for 15 to 20 minutes in a temperature bath and then rapidly dried, whereupon the spectrophotometric determination was carried out. The change in temperature during the spectrophotometric determination was checked by means of another tube, which was simultaneously subjected to the same treatment, the temperature of the latter tube meanwhile being measured both before and after the spectrophotometric determination. The temperature figures thus obtained can be regarded as accurate to ca. 1° C. The results are shown in Table 4 and in Fig. 2, on the left. We note the fact already mentioned, — and further verified by several experiments not recorded here — that the indicator ionization (proportional to ε) in the case of acid solutions increases and in that of alkaline solutions decreases with rising temperature. By graphic interpolation from the left hand system and by using WALBUM's pH temperature coefficients as given in Table 1, the system shown on the right was set up, and shows the displacement of the indicator transformation curve with temperature. In theory such a parallel displacement implies a change in the value of pK, rendering it possible to calculate the temperature coefficient (alteration of pK per 1° C.) of the latter. In the case of cresol red a mean value of 0.0053[1]) was found. Consequently, when use is made of cresol red, the equation for calculation of the pH of the water is

$$pH_{t_w} = pH_{t_b} - 0.0053\ (t_w - t_b)$$

Example. A sample of water, the temperature of which at the moment of collection is $t_w = 2°$, is colorimetrically determined by a buffer series, with a temperature of $t_b = 25°$. It is found to be identical in colour with a buffer tube inscribed $pH = 8.0$. By the aid of Table 1 we find that $pH_{t_b} = 7.98$

$$pH_{t_w} = 7.98 - 0.0053\ (2-25) = 8.10.$$

The influence of temperature ought in theory to consist solely in a parallel displacement of the transformation curve. From fig. 2 it is nevertheless apparent that the alteration for temperature changes of equal degree is not the same at every part of the curve, being greater in the more acid portion. In this respect cresol red differs from the indicators previously tested by the author. This circumstance finds no explanation

[1]) Negative sign, as pK declines with rising temperature.

Table 4.

t	pH	Extinct. coeff ε	Degree of Trans-form. %	t	pH	Extinct. coeff ε	Degree of Trans-form. %	t	p
12.5	8.68	0.846	77.3	11	8.07	0.489	44.7	12	7
19.5	8.65	0.838	76.7	19	8.05	0.495	45.3	19.5	7
36	8.56	0.825	75.4	36.5	7.99	0.514	47.0	32	7

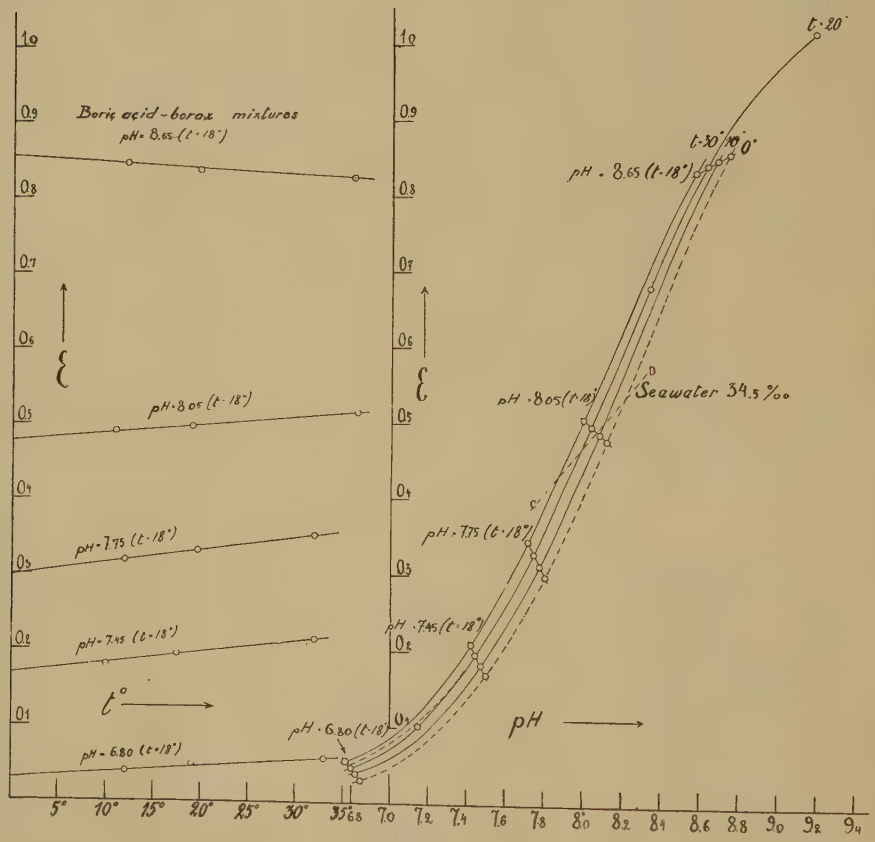


Fig. 2.

in the theory in its simplest form. In practice this deviation is of minor importance. The indicator should be used only within the pH range in which the curve is almost linear, and which coincides fairly closely with the pH range of sea-water; within this range the errors arising

Table 4 (continued).

nct. ff	Degree of Trans- form. %	t	pH	Extinct. coeff ε	Degree of Trans- form. %	t	pH	Extinct. coeff. ε	Degree of Trans- form. %
317	29.0	10	7.47	0.181	16.5	12	6.81	0.040	3.7
332	30.3	17.5	7.45	0.195	17.8	19	6.80	0.049	4.5
352	32.2	32	7.42	0.215	19.6	33	6.78	0.058	5.3

from the differences in question lie within the other experimental errors. The value assumed, 0.0053, is an average of the values at the limits of this indicator's range.

4. Cresol red and Sea-water at different Temperatures.

With the determination of the temperature coefficients of the *pH* of the buffer solutions and of the *pK* of the indicators, the data necessary for correct determination of the *pH* of the water are known. To enable us to judge correctly the conditions, in which work with *pH* measurements in the open air should be undertaken in order to assure the most accurate results, it is necessary to know how the water alters its colour and *pH* in changing temperatures. The latter question has already been solved by the author[1]) by a series of spectrophotometric *pH* determinations, in which different indicators were used at varying temperatures, and by some measurements referring to different buffer series (borax and phosphate). Independently of the conditions under which the measurements were carried out, they led, in agreement with the theory, to practically identical results, *viz.*, that the *pH* of sea-water decreases by 0.012 units when the temperature rises 1° C. The result arrived at was the mean value of 10 determinations carried out in various ways and differing from one another within the limits ± 0.002 units. If the temperature of the water rises by, for example, 10° C. without its composition being altered through any loss of CO_2, the acidity of the water increases by 0.12 *pH* units. From this it appears that temperature is by no means negligible with regard to the formation of *pH* conditions in nature.

In order to check the colour change of cresol red in sea-water, the *pH* was determined at two different temperatures with this

[1]) K. Buch: Loc. cit. Merentutkimuslaitoksen julkaisu Havsforskningsinstitutets skrift N:o 61. P. 19. 1929.

indicator also, the mode of procedure being as follows. A sample of sea-water, 34.5 $^0/_{00}$, received an admixture of indicator and was first spectrophotometrically examined at ordinary temperature. Thereupon the same tube was cooled and heated several times in succession, being spectrophotometrically examined after each change of temperature. The temperature was checked by means of parallel tubes. By taking the mean variation of heating and cooling, the result indicated by the line C—D fig. 2 (the system on the right) was obtained. If the temperature rises 30° C. the *pH* value declines by 0.36 units, or 0.012 units per 1° C., in agreement with the earlier mean value given above. With such an alteration of 30° C. in temperature, the light absorption value declines by 0.105 ε-units. If the corresponding *pH* alteration is read from the curve for 20° C., one arrives at not more than 0.18 *pH*-units, or merely the half of the actual figure. If a sample of water is taken for purposes of colorimetric determination and rises say 10° C. before the measurement is taken, the indicator colouring is lessened by an amount which would correspond to 0.06 *pH*-units on reading the buffer scale. We should thus obtain a value which would be this much too low.

An instance may be given of the *pH* values obtained by colorimetric determination according to the different methods in use. For the sake of simplicity we may assume that the temperature of the buffer series is 18° C., the temperature of the water on collection being $t_w = 2°$. On immediate colorimetric determination the water is found to be identical in colour with a buffer tube inscribed 8.00, a value which consequently, if the temperature factor were to be neglected, would be regarded as correct. On heating the water to 18° C. and on the assumption that no CO_2-alteration takes place, the colour alters in an acid direction, in agreement with the tests already mentioned, the buffer scale showing a *pH* value of 8.00—0.006 × 16 = 7.90. The correct value is obtained from the value arrived at on immediate colorimetric determination in accordance with the equation

$$pH_{t_w} = 8.00 - 0.0053\ (2—18) = 8.085.$$

The water may also be heated, however, to the same temperature as the buffer. Should this be done, the calculated value of *pH* must be corrected with the amount by which the indicator colour has changed in an acid direction during the heating process. The resulting equation is

$$pH_{t_w} = 7.90 + 0.0053 \times 16 + 0.006 \times 16 = 8.085.$$

The carrying out of pH Determinations in practice.

The indicator theory and the tests carried out show that in order to arrive at the greatest possible accuracy in taking measurements of *pH in situ*, heed must be paid to certain circumstances, which may be summarized as follows:—

1) In determining *pH* by the aid of indicators and standard solutions, effort should as a rule be made to keep the fluid under examination and the standard solution at one and the same temperature, *viz.*, that of the fluid *in situ*.

2) As the principle mentioned in 1) cannot always be adhered to, a note should always be made of t_b, the temperature of the standard solution, as well as of t_w, the temperature *in situ* of the fluid under examination. Should it be found impossible to avoid changes of several degrees in the temperature of the sample during the measurements, the temperature of the sample at the moment of measurement should also be noted.

3) The standard solutions should never be kept at a temperature of less than 10°.

4) The *pH* of the water sample *in situ* should be calculated according to the equation

$$pH_{t_w} = pH_{t_b} + \alpha\,(t_b - t_w)\,[1]).$$

Here for pH_{t_b} is inserted the *pH* value found on colorimetric determination, corrected according to Table 1[3]), and for α, depending on which indicator has been used, one of the following values:

cresol red	$\alpha = +0.0053$
phenol red	$\alpha = +0.010$
α-naphtholphthalein[2])	$\alpha = +0.0084$
phenolphthalein	$\alpha = +0.010$

[1]) For the sake of simplicity we have here, in contrast to our earlier procedure, changed the signs in the second term, in order to allow the α-values to be used with a positive sign, instead of a negative, as for reasons already pointed out should properly be the case.

[2]) α-naphtholphthalein should not be used at temperatures approaching 0° C., as the colour fades at this temperature for reasons as yet impossible to explain by the theory now put forward.

[3]) It should be remembered that Table 1 applies to borate buffer solutions only.

5) If the temperature of the sample under examination is several degrees higher at the time of measurement ($= t'_w$) than when collected, ($= t_w$) the correction $\beta\,(t'_w - t_w)$, should be added to the above equation in which β has one of the following values:—

cresol red	$\beta = 0.006$
phenol red	$\beta = 0.004$
naphtholphthalein	$\beta = 0.004$

Phenolphthalein needs no correction in the above respect. And in most instances this correction will probably not be needed for the other indicators also.

A Surface Sampler for Temperature Observations.

By

J. R. Lumby,

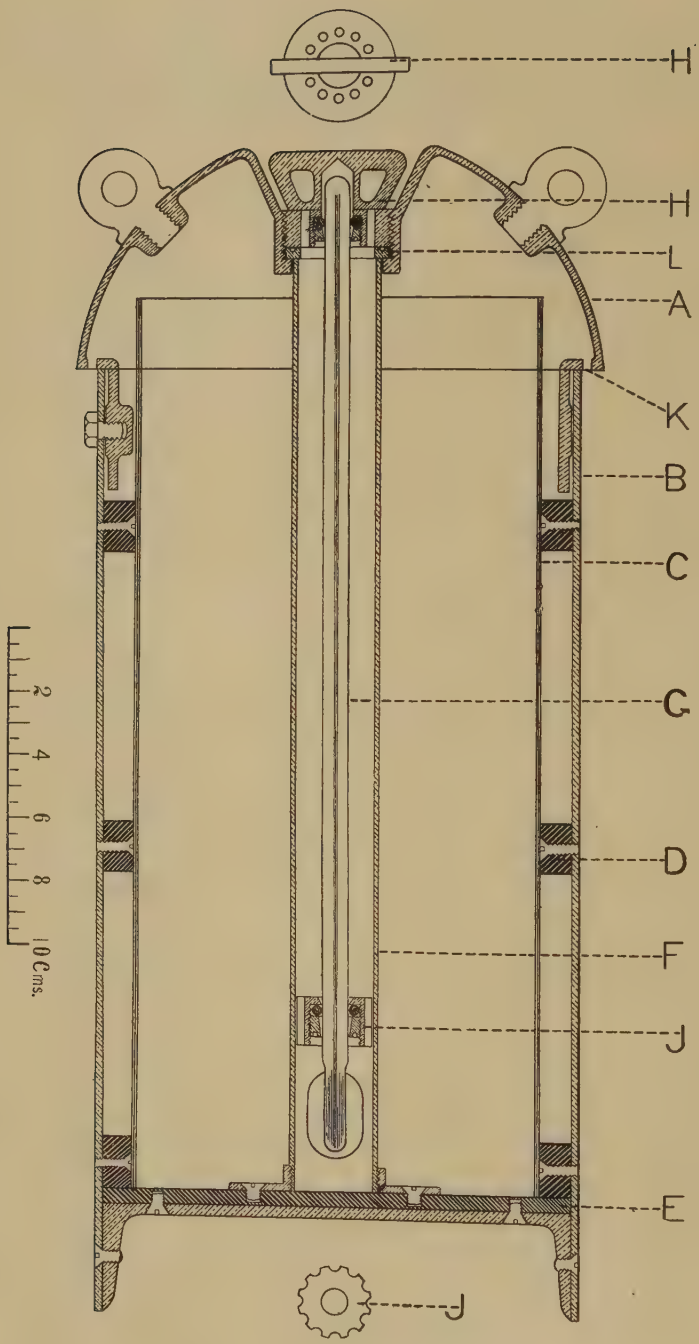
Fisheries Laboratory, Lowestoft.

Two models of the Surface Sampler for use from commercial ships have been described previously in this Journal[1]). The first model was intended principally for the purpose of bettering the collection of water samples intended for subsequent chemical analysis ashore, by providing for automatic washing of the sample bottle, which was contained in the apparatus. The second model combined the improvement already made in the collection of the sample with increased accuracy of temperature observation. In addition to the sample bottle, a thermometer was made part of the instrument, and the water sample was insulated. The model now to be described was designed for use when temperature observations alone are the object, and samples are not required for analysis ashore.

In general, the new type of Surface Sampler is similar to the second type mentioned above, in which both the sample bottle and thermometer are included. It consists, as before, of head (A) and body (B), which are now bolted together. The observations can be made without removing the head from the body, and it is only necessary to do so for cleaning or repairs. The water sample is insulated by means of a celluloid liner (C) kept in place by ebonite distance pieces (D). The insulation is completed at the bottom by means of an ebonite sheet (E) to which a brass tube (F) containing the thermometer (G) is screwed, The upper end of this tube fits into the opening in the casting forming the head.

The thermometer is held by two glands, which compress rubber washers on to the thermometer tube. The upper gland (H) is furnished with a thumb-piece by which it can be handled. It is screwed into the casting of the head and keeps the thermometer in place. Holes are pierced through this gland, which allow water to flow into the tube (F) containing the thermometer. The lower gland (J) which is free to slide in tube (F) is also cut to allow water to flow past. The total area of the cross sections of the channels in the upper gland is nearly twice the cross section of the pipe through which the water entered the glass bottle in the other, earlier models.

[1]) Journal du Cons. II. 3. 1927 & III. 3. 1928.


H
H
L
A
K
B
C
C
D
F
J
E
J
2
4
6
8
10 Cms.

The water flows round the bulb of the thermometer and passes through ports in the tube (F) and so into the cavity of the body. When this is filled, the water leaves the apparatus through a series of ports (K) on the under-side of the head.

The apparatus is towed in precisely the same manner as the models previously described. When it is brought inboard, all that is required is merely to unscrew the upper gland and raise the thermometer until the mercury column can be seen. A ring (L) screwed down below the upper gland, checks the lower gland, and prevents the bulb of the thermometer being withdrawn from the water, accidently or otherwise. Since there is no necessity to wait for the thermometer to reach the temperature of the water, as with an ordinary bucket, there is little opportunity for the temperature of the water sample to alter. The insulating liner is an additional safeguard against this event.

The price of a Surface Sampler of this type would be approximately £5. The price of a Surface Sampler fitted to contain both glass bottle and thermometer is about £8, while the non-insulating type, to contain the glass bottle alone, costs about £3. The makers are Messrs. Elliott & Garrood, Beccles, Suffolk.

A word may be said here as to the economy of using these instruments, the initial cost of which is, in comparison with an iron or canvas bucket, admittedly high. In the first place, more reliable observations can be obtained with this apparatus than with an ordinary iron or canvas bucket, and the standard of accuracy can be raised so as to make the observations comparable with research ship observations. Moreover, iron buckets do not last very long under the rough treatment they have to undergo in use from fast ships. One Surface Sampler was used weekly from a 20 knot ship for nearly three years. At the end of this time, it was withdrawn in favour of the improved model: it had evidently received very severe buffeting, yet it required very little attention to make it fit for use again. Since all the ships observing for the Ministry of Agriculture and Fisheries were furnished with Surface Samplers in October 1928, only one Sampler (out of 17 in use) has been so damaged as to need more than trifling repairs. Since first writing, accidents have occurred to two of the Samplers in use (containing both bottle and thermometer) which point to a failure of the spring safety catch, owing to one of the screws shearing. In future models, therefore, this part of the apparatus will be strengthened. Loss of the body can always be further guarded against by fitting a preventer wire from the head to an eye-bolt in the base.

In conclusion, I have to acknowledge my thanks to Mr. W. Johnston for preparing the diagram accompanying this text.

Note on the Northern Limit of the Distribution of *Rhincalanus Nasutus* Giesbrecht.

By

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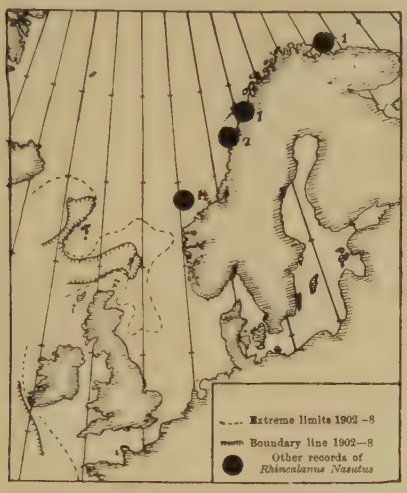
Sars (1903) states that *Rhincalanus nasutus* Giesbrecht had not hitherto been found in Norwegian waters: (p. 16) "Though not yet found in the immediate vicinity of the Norwegian coast, this form has a claim to be included in the fauna of Norway." According to Farran (1910) the species is not seldom met with in the Atlantic waters of the southern Norwegian Sea, and he has also shown (Pl. IX) the limits of its extreme distribution over the area within which observations were made during the International investigations, 1902—1908 (Fig. 1). During the investigations carried out by Hjort and Ruud off Møre 1925—1927 (Ruud 1929) 14 specimens were caught off Storeggen in pure Atlantic water somewhat farther to the North than the position of the most northern observation mentioned by Farran (63°32′ N., 5°39′ E.[1]). These observations will evidently give us the normal distribution of the species to the North in years when the hydrographical conditions are normal.

The most northern observation of this copepod was made during the Russian investigations off the Murman coast in the years 1899—1900 (Linko 1907), — 31.III.1899, one fullgrown specimen of *Rhincalanus nasutus* from a haul from 68—0 metres at 69°57′ N., 32°25′ E., the temperature being + 1° C. "Probably *Rhincalanus nasutus* appeared in our waters in 1899 only because of extreme external conditions; the phytoplankton in 1899—1900 was considerably richer in species than in the following years. It contained a certain amount of southern (Linko: western) forms which later on were rare or were not met with at all. The appearance of these species, among which *Rhincalanus nasutus*

[1]) Ruud's position 63°32' N., 50°39' E. must be due to a misprint.

occurred, I have connected with the phenomenon that in my opinion there was a stronger supply of the warm Atlantic water into the Barents Sea for these particular years mentioned above." (LINKO 1907, p. 168, translated from the Russian).

During my investigations of copepods from the northern Norwegian coast, based on material which has kindly been placed at my disposal by Mr. O. SUND, Norwegian Fishery Board, I have never found *Rhincalanus nasutus* among the several hundred samples from the years



Map showing the normal distribution of *Rhincalanus nasutus* from FARRAN 1910 and the records along the Norwegian and Murman coast with the number of individuals from each haul.

1922, 1923 and 1924, which I have examined. In the 31 samples from the West Fjord collected by Mr. SUND during the spring 1929 I have, however, found 5 specimens of *Rhincalanus nasutus*. Two specimens were caught in a haul from 150—0 metres at the mouth of the fjord (67°23′,9 N., 12°33′,5 E., 12.IV.1929; temperatures from the station being; 75 metres 5,46° C., 0 metres 4,03° C., salinities; 75 metres 34,42 ‰, 0 metres 33,74 ‰ 1 male, length of cephalothorax 3.9 mm., 1 female, length of cephalothorax 4.6 mm.). Two samples from this locality 29/IV 1929 brought two more specimens. A fifth specimen was recorded in a haul from 150—75 metres in the inner regions of the fjord (68°18′,3 N., 15°54′,2 E.; temperature and salinity at 75 metres: 6,50° C., 34,60 ‰. 1 female, length of cephalothorax 4.1 mm.).

Professor GRAN, who has examined the samples of phytoplankton collected in the Romsdalsfjord this spring has kindly permitted me to

publish his statement that southern species were very common in the fjord this year. It thus seems to me that this year we have an abnormal invasion of southern forms into the Norwegian waters under circumstances very much like those found by LINKO in the years 1899 and 1900 on the Murman coast.

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1929. RUUD, J. T. On the Biology of Copepods off Møre 1925—1927. Rapports et Procès-Verbaux LVI, Copenhague.

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Preliminary Note on Experimental Trawling with Cod-End Meshes of Different Sizes.

By

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Fisheries Laboratory, Lowestoft.

1. General.

The general lines on which work is being developed by the Ministry of Agriculture and Fisheries with regard to fishing apparatus to which the term "Savings Gear" has come to be applied may briefly be stated as follows:— The testing of new apparatus designed to spare undersized fish and the modification of the existing gear used by commercial trawlers, in such a way that fish which are of almost marketable size may be allowed to escape and live until they have reached at least the lowest market category.

It is clear that the simplest problem is that presented by round fish, and most of the research work has been carried out on such fish and principally on haddock. The intense conservatism of the fishing industry has been borne in mind, and, as far as possible, work is confined to schemes entailing no radical departure from the ordinary design of the otter-trawl.

The problem has been treated as being of a practical and economic rather than of a purely biological nature, since it is obvious that, although it would appear impossible completely to fish out any species (regardless of size and age), the present method of capturing and killing large numbers of a species just below the size at which they become of commercial value is extremely wasteful.

For example, say the size at which the members of a certain species become marketable may be represented by a length of x cm. and the mean growth of individuals during the year before they reach that length is y cm. per annum; it is then obviously wasteful to capture any

fish between x—y and x, since the fish of length x—y cm. will in the course of a year's growth reach length x cm. The extra months of life for these, the smallest of the fish under consideration, would convert them from a useless litter on a trawler's deck into a useful, marketable article. The extra life necessary for fish greater than x—y but less than x would of course be less.

Although it is obvious that the catching and killing of fish just before they are of marketable size is wasteful, we have little or no knowledge as to the effect of sparing all fish of under-marketable size. It is conceivable that a consequent accumulation and overcrowding of the lower sizes might produce a slow growth-rate for the species. Such a phenomenon appears, at first sight, conducive to irrational and uneconomical "farming of the sea". The writer is inclined to believe that did such an accumulation occur, even if accompanied by overcrowding, it would react favourably rather than unfavourably on fisheries.

For instance, supposing the mesh in use released the majority of a certain species below x cm. then a certain amount of fish of that species would pass length x every year and become of commercial value. It seems to the writer that the fact that the growth might be slow is immaterial. The accumulated stock would form a "pool" and act as a "shock absorber" which will damp down the effect of a bad survival year of the 0-group producing a bad fishing year. On the other hand, a fishery which is dependent on a sparse, fast growing population of, on the average, only sufficient magnitude to supply the demand, is extremely hard hit by any year of bad survival and therefore very unstable.

It may be taken that 26 cm. is the size at which the haddock becomes regularly and consistently marketable, and this length coincides roughly with the end of the second year of growth.

2. Methods.

The data on which this paper is based consist of hauls with a standard No. 4 Granton Trawl (headline 80 feet, ground rope 120 feet) fitted with cod-ends of various meshes. The cod-ends were in some cases fitted with a cover of fine meshed net. Throughout the experiments the cod-ends were made of material such as would normally be used by commercial trawlers, the only difference being in the size of the mesh. This material was 3 ply manilla 100^{s}[1]) doubled as is the general rule on commercial steam trawlers.

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[1]) i.e. 100 yards to the pound.

Fig. 1.

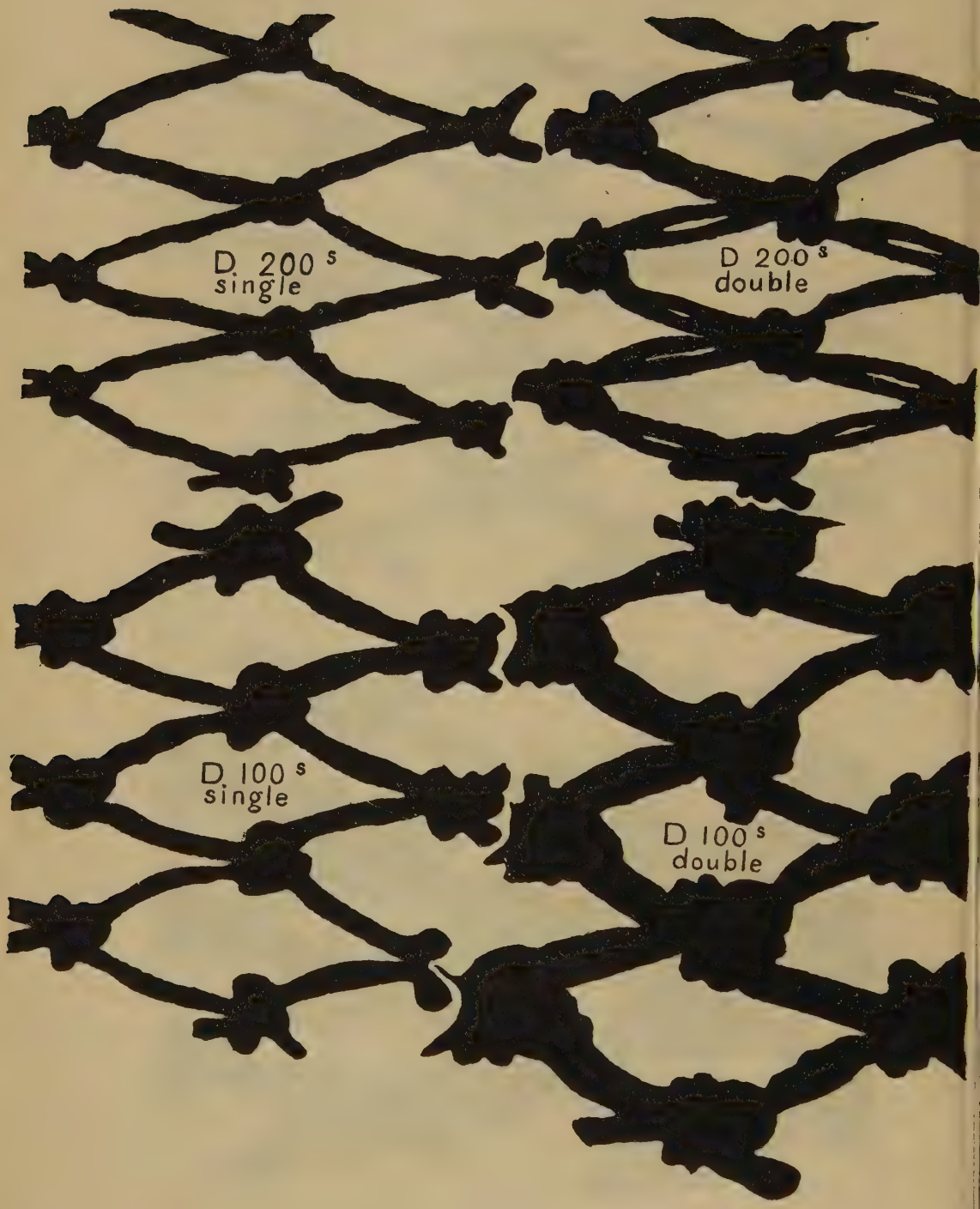

Fig. 2.

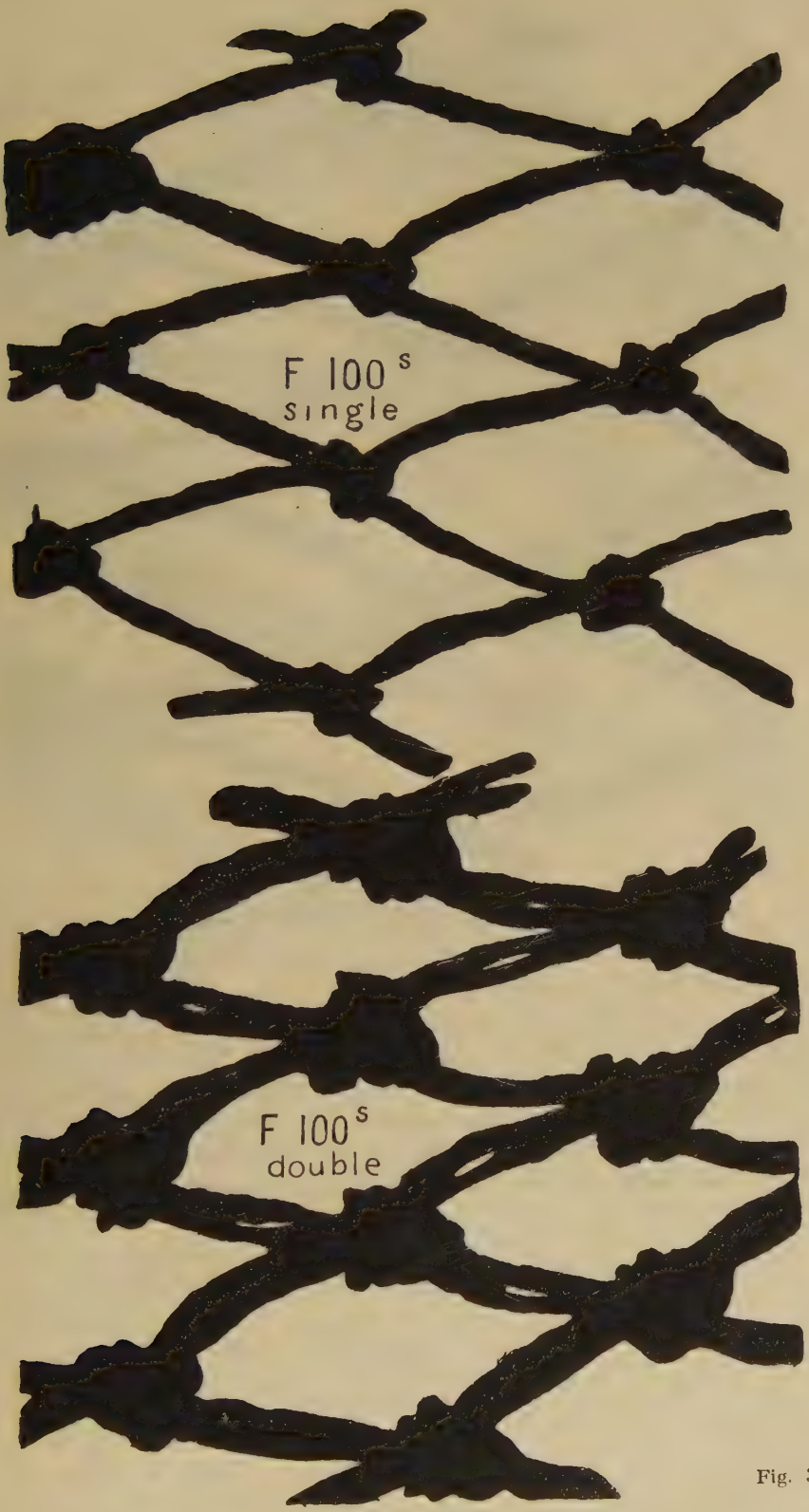

Fig. 3.

Fig. 4.

Previous to the actual experiments at sea a certain amount of work was carried out with a view to discovering the probable effective lumen of meshes made on spools of various sizes and of twine of various sizes both single and double. The circumference of the spool may be considered as being roughly equal to half the circumference of the lumen of the mesh, or to the total length of the lumen of the mesh when stretched to its fullest extent in a fore and aft direction, due allowance having been made for the thickness of the twine. The spools used were as follows:—

C,	circumference	5 cm.	F,	circumference	8 cm.
D,	—	6 -	G,	—	9 -
E,	—	7 -	H,	—	10 -

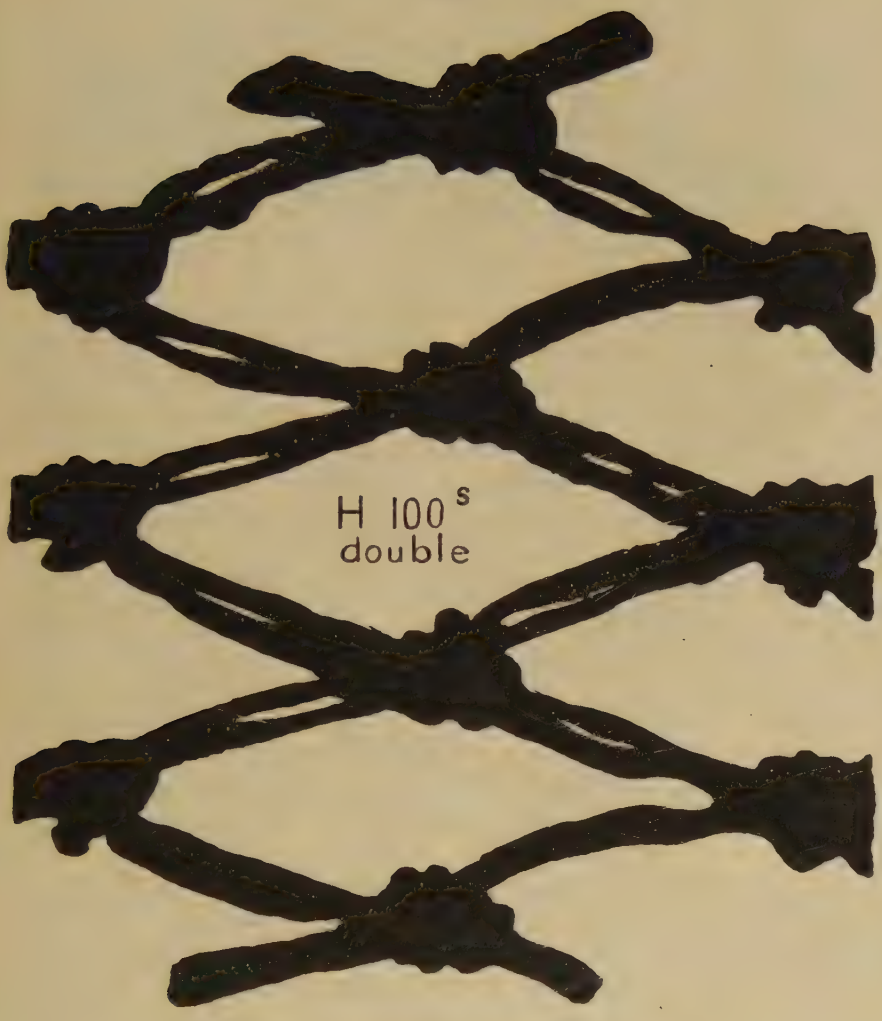

Fig. 5.

Contact prints were made of samples of net made on these spools and tracings of them are shown in figures 1 - 5. The great difference in lumen according as to whether the mesh is made of single or double twine and according to the size of the twine is obvious as is also the great reduction of lumen produced by the knots in some cases.

In general, the laboratory work with gauges seemed to indicate that one of the main factors influencing the size at which a fish would pass through a mesh of a given size was the maximum breadth of the fish whether flat or round.

As regards the sea work, experiments were continued with the trouser

cod-end previously described in this Journal[1]), but were eventually discontinued after they had given indications of the best sizes of mesh with which to carry out the main experiments. The trouser cod-end, though most useful for providing rough indicative data at small cost, is not considered reliable for fundamental experiments, as, in addition to its obvious limitations, as compared with a normal commercial cod-end, it shows a tendency for the after[2]) leg to take a considerably larger amount of fish.

The main experiments were carried out in the North Sea on haddock grounds with cod-ends made on the 10 cm. spool and to the South-west of Ireland on hake grounds with cod-ends made on spools of 6, 8 and 10 cm. circumference, the twine being that specified above (3 ply manilla 100^s) and untarred. The measurements of the meshes made on the 10 cm. spools averaged 23 rows per yard under working conditions with very little variation under all conditions. This represents a knot to knot lumen of 7—8 cm. (ca. 3 inches) when the mesh is stretched fore and aft.

It has often been stated verbally, and it is the belief of many workers, that the covering of a cod-end with shrimp netting causes it to retain a higher proportion of small fish than does a cod-end fished without a cover. It is stated that either the cover "spoils the draught" of water through the net or lies close against the meshes of the cod-end, thus preventing the passage of fish through them. The writer therefore carried out preliminary experiments to find out whether a well made and well set cover had any effect on the proportions of the fish retained at various sizes.

It is obvious that if the cover is closely applied to the main cod-end and does not form a clear bag when the net is being towed, there must be a blanketing effect. A cover that will flow clear and not sag onto the cod-end is therefore a necessity. The cover used by the writer was similar to that used in the Swedish experiments on the Savings Trawl. The shrimp netting was supported clear of the cod-end by means of rattan canes and there was thus formed above the cod-end a spacious chamber which continued backwards. The underside of the main cod-end was also lined with shrimp netting. This reason for this step was that, as the underside of a cod-end is already blanketed to a certain extent by "false bellies" or "rubbers" and by its close application to the bottom, it was thought that the data would be easier to interpret if the escape

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[1]) Russell and Edser. Vol. I, No. 1.

[2]) i.e. the leg which lies aft when the net is being hauled alongside the vessel. When the gear is being hauled on the starboard side it is the port leg.

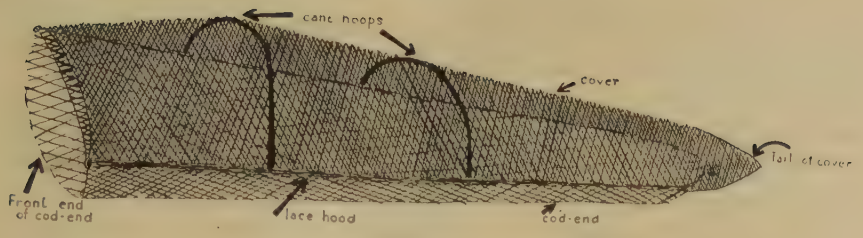

Fig. 6.

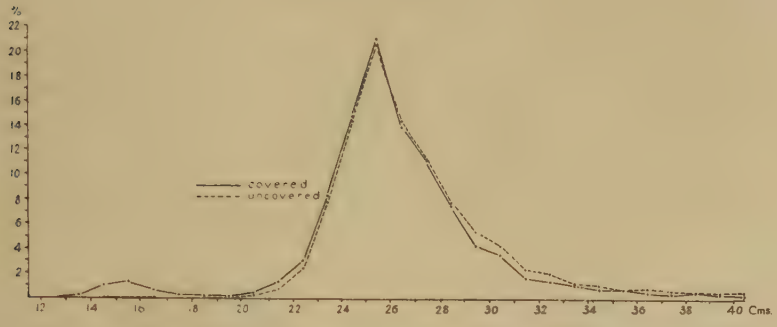

Fig. 7. Voyage C 1929. Percentage of Haddock retained at each centimetre length in cod-end both covered and uncovered. (12 hauls of each.) Ordinary Otter-Trawl.

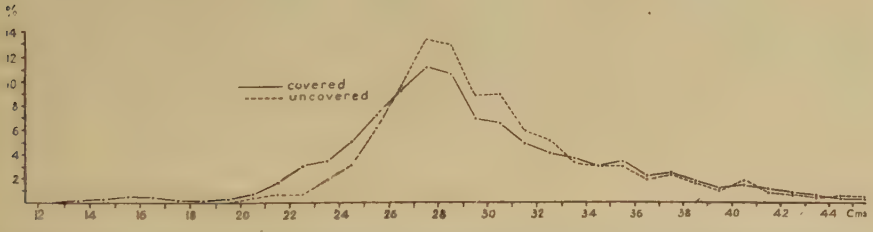

Fig. 8. Voyage D 1929. Percentage of Haddock retained at each centimetre length in cod-end both covered and uncovered. (5 hauls of each.) Modified V.D.

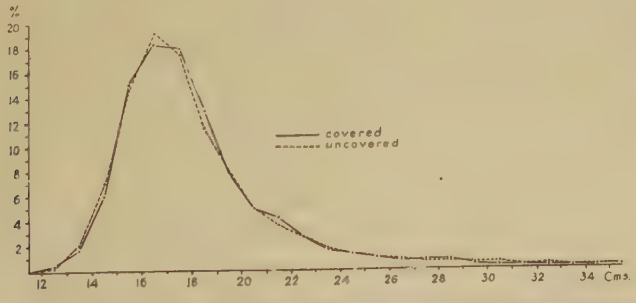

Fig. 9. Dabs. Cruise C 1928 and D 1928. Percentage of Dabs retained at each centimetre length in cod-end both covered and uncovered. (6 hauls of each.) Ordinary Otter-Trawl.

of fish from the underside of the net were completely eliminated. Figure 6 shows the cod-end and cover but not the lining of the underside.

24 hauls were taken with the trawl, and the 10 cm. cod-end was fished, covered and uncovered in alternate series of three hauls each.

The percentage of each length of fish retained in the cod-end was calculated for the covered and uncovered series. The results, which are based on 7,767 haddock in the uncovered and 7,805 in the covered cod-end, as shown in fig. 7, show little difference in the two frequency distributions.

A further experiment was carried out with 10 hauls of the same trawl fitted with 30 fathom ground warps, Dan Lenos, and glass balls on the headline, in other words fitted as a "modified Vigneron-Dahl." This experiment (Fig. 8) did not give such satisfactory results, but the fishing appears to have taken place on a very irregular population; 2,814 haddock were taken in the uncovered cod-end and 4,158 in the covered.

Earlier tests on small dabs with a standard $2^1/_2''$ cod-end which released 46 % of fish of 19 cm. and under gave strikingly good results (Fig. 9).

In the light of this evidence the writer is of the opinion that a well made, roomy cover well supported by canes gives reliable results, and that the use of covered cod-ends is superior to the more laborious method of alternate hauls or series of hauls with a small meshed cod-end and the large meshed cod-end under investigation.

3. Results.

The results of the main experiments on haddock are shown in Fig. 10 where the numbers of fish taken in the cod-end and cover are shown for the ordinary otter-trawl (A) modified V.D. (B), and the total for both types (C) the points on the graphs being the results of 3-point smoothing of the actual figures. It is obvious that in the two former cases and, of course, consequently, for the latter the lengths at which 50 % are taken and 50 % released are practically the same, namely 23.5 to 24 cm.

Fig. 11 shows the percentage of haddock released at each cm. length based on all hauls with the covered normal Granton Trawl and the same net modified as a V.D. and covered. It would be convenient at this point to have a rough and ready index of the sharpness of selection of a net. Now a net with a 100 % sharpness of selection would release all fish being released below the selection point and retain all above it.

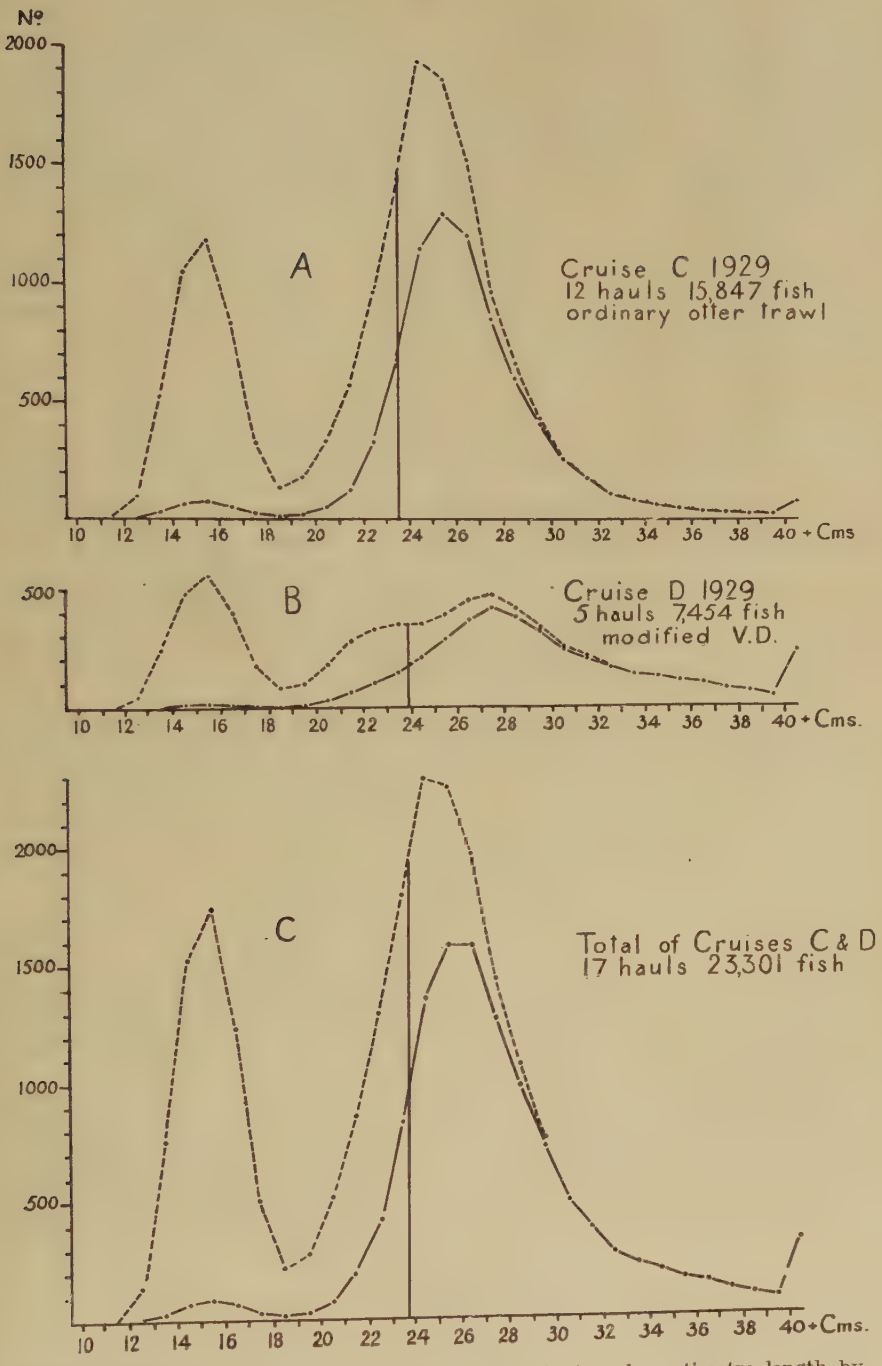

Fig. 10. Number of Haddock retained and released at each centimetre length by 10 cm. cod-end

cod-end ---------- cod-end plus cover —·—·—·—·—

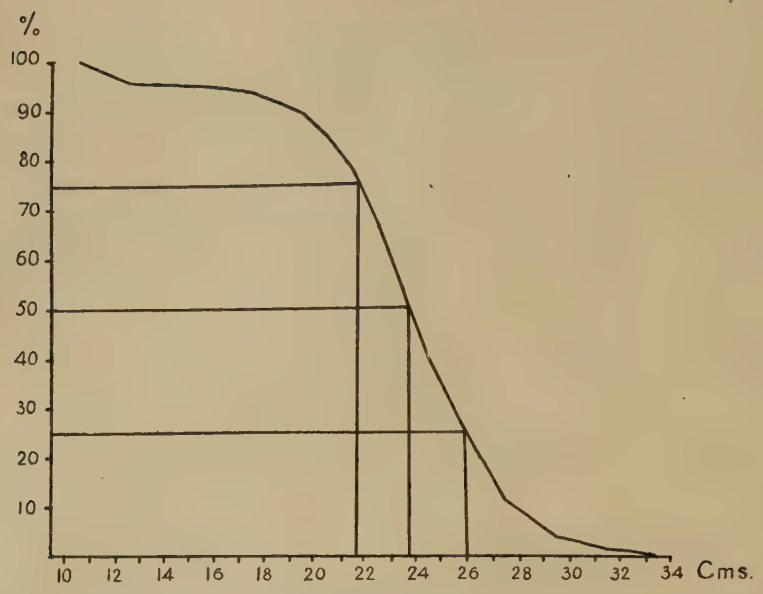

Fig. 11. Haddock. Percentage released at each centimetre length by 10 cm. mesh. Otter and Modified V.D.

My colleague, Mr. H. J. B. WOLLASTON, suggested the following formula which in common with others[1]) would give for the net of 100 % efficiency of selection, the number 100. $x = 100 \left(\frac{M - i.r.}{M}\right)$[2]). In the case of the data taken graphically from Fig. 11 the result would be

$$x = 100 \left(\frac{23.8 - 4.3.}{23.8.}\right) = 82.$$

This question of the sharpness of selection is important since the greater the sharpness of selection the less marketable fish are released along with the unmarketable.

Assuming that 26 cm. is the limit above which haddock are always marketable, then this cod-end, according to the experimental data, loses 11 % of marketable fish up to 33 cm. and releases 52 % of the unmarketable above 18 cm. the latter being exclusive of the fish of less than 18 cm. which of course mostly escape capture. Actually the saving of fish below 18 cm. amounted to 95 %.

[1]) See paper in this number pp. 300 et seq.

[2]) M = Mean-Length at which 50 % are released and 50 % retained. i.r. = Interquartile range = difference between lengths where 75 % are released and 25 % are released.

The net result is that given a mesh of this type in common use practically the whole of the 0-group (i.e. under 18 cm.) is able to survive and 50 % of the I-group (i.e. under 26 cm.) has a chance of attaining marketable size. The loss of the 11 % of the fish of 26 to 33 cms. of course may be a much smaller percentage of the total marketable catch (in this case 9 %). The actual percentages released at each cm. length were as follows:—

cm.	26	27	28	29	30	31	32	33	34 & over
%	20.0	11.4	8.1	4.5	3.3	1.5	1.1	0.4	0.0

The data on which these results are based are for the beginning of the growth period and the end of the period of least growth, i.e. March. Before the results can be considered sound and authoritative it is necessary for the experiments to be repeated towards the end of the growth period when a larger number of fish near the point of release are present. This is being done during the present year.

Work has also been carried out on the hake grounds to the SW. of Ireland with covered cod-ends made on spools of 6 cm., 8 cm. and 10 cm. clear, 13 hauls being taken with the first (5359 fish), 22 hauls with the second (5716 fish) and 17 with the last (6271 fish). It is not proposed to discuss in detail the possible effects on the hake stock of using larger meshes as the data are not yet sufficiently extensive. The actual results were as follows:—

6 cm. mesh. All fish retained at 22 cm. and only 3.5 % released at 16 cm.

8 cm. mesh. 75 % released at 17 cm., 50 % at 21 cm., 25 % at 23 cm. All retained at 30 cm.

10 cm. mesh. 75 % released at 22 cm., 50 % at 26 cm., 25 % at 29 cm. All retained at 41 cm.

In general it appears that the use of the 10 cm. mesh would have a beneficial effect on hake as well as on haddock.

Further experiments with the 10 cm. mesh both on haddock and hake are due to be carried out in the near future.

The Selective Action of the Gelder Cod-End and that of other Cod-Ends compared.

By

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Fisheries Laboratory, Lowestoft.

On rereading Todd's paper, published in 1911[1]), on experiments with trawls having covers of fine-meshed netting I was interested to notice that a series of experiments was made with a beam trawl ("Beam trawl V") having a cod-end of ordinary mesh but supported by an oval hoop of 139 × 88 cm. diameters. Eleven successful hauls were made with this gear. It is important to bear in mind the functional differences between such a cod-end, called here for convenience type B, the Gelder cod-end, (Type C), which is supported by two frames some distance apart, and the ordinary unsupported cod-end (Type A).

If the meshes of a cod-end were quite rigid and so supported that their shape and dimensions were invariable, and if a fish of any given length were also rigid and invariable as to the dimensions and shape of its cross-sections, selection by a net would, if every fish attempted to escape, be dead sharp or "knife edged" (see Wollaston[2]). Supporting a net as in Type C so that the meshes are held open in a fairly definite shape certainly eliminates an important cause of selective variation. Supporting it by one frame as in type B has no tendency to standardise the shape of the meshes, this varying continuously as we pass from meshes near the frame to those distant from it, the latter taking more and more the shape of the meshes of an unsupported cod-end the further they are from the frame. True, all the meshes are held rather more open than those of Type A. In the unsupported cod-end, there is again really no standardisation of shape, since meshes in different positions will vary in shape according to the flow of water through them and according

[1]) Todd. Covered Net Experiments. Int. Invest. Report III. 1911.

[2]) Wollaston. On the Selective Action etc. Journ. du Cons. Vol. II. No. 3. 1927.

to the amount of distention due to contained fish and "rubbish". On the whole though there must be a great tendency for the meshes in Type A to be definitely somewhat closed, by longitudinal stress on them, against egress of fish.

We should therefore expect the selective action of Types A & B to be blunt or diffuse and that of C to be much sharper.

The "position"[1]) of the selection curve in Type C depends on whether the meshes are held at a shape suitable to allow the escape of the particular fish in question. It is obvious that for a flat, wide fish, such as a plaice, the selection curve will be higher in position[2]) if the meshes are held in a long diamond shape than if they are square.

Data dealing with the selective action of the Gelder cod-end on the plaice were published in a brochure, "The Savings Trawl", which was prepared for the meeting of the International Council for the Exploration of the Sea in London, 1929. Those given in Table I of this brochure have been used here, but corrected as detailed later. To compare with these we have used data given in Todd (*loc. cit.*) in Table B, namely those given under the headings "Beam I" and "Beam V". The cod-end used by Todd had a mesh of 5.6 cms. stretched, while the mesh of the Gelder cod-end was 8 cms. stretched.

A modification of the method given in my previous paper on the Selective Action of a Trawl Net has been used for the work of comparison. The mathematics of the modified method are of a quite elementary nature, and the time necessary for its application is very short, while it gives a definite result free from the personal equation. The method as applied to Todd's "Beam V" figures is as follows:—

Arrange as a column the percentages caught at each cm. (A)[3]). Write down their differences (B). Find the logs of the highest difference and of one on each side of it (C). Fit the parabola $y = a + bx + cx^2$ to the three logarithms by calculating the constants as shown. The curve will pass through the three points chosen and points may be extrapolated by substituting $x = -2$ for 12.5 cms., $x = 2$ for 16.5 cms. and so on. The antilogs are then found and the differences added up to give Column (F). It will be noticed that the calculated sum-curve or ogive (F) passes through four of the original points. The curve represented by (E) is a curve of error, but the ordinates of the curve to which it is fitted represent areas, each ordinate representing the percentage added between two adjacent centimetre lengths. The steepest point of

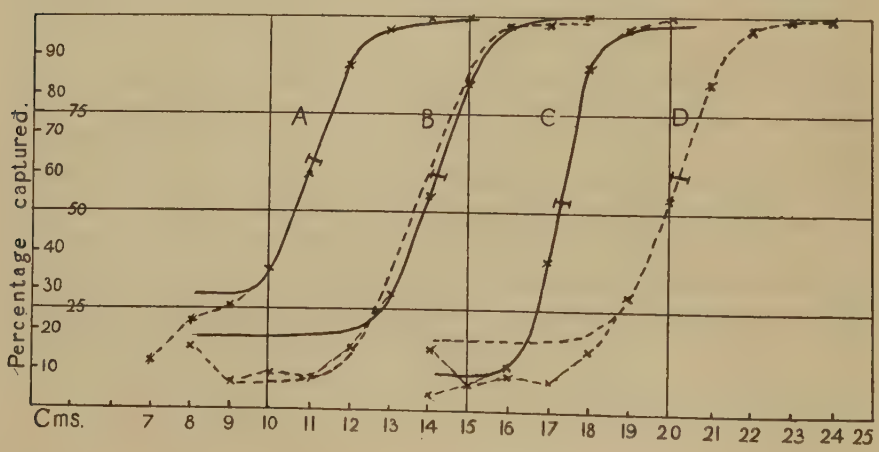
[1]) See Table on p. 303.

[2]) i.e. will act on larger fish.

[3]) p. 306.

the curve drawn from (F) corresponds to the mode of (E). Antilog Y_0 represents the greatest one centimetre increase of percentage capture, the corresponding centimetre being that extending to half a centimetre on either side of the mode. Antilog Y_0 thus serves as a very good Coefficient of Sharpness in selective action and I propose to use it as such here. We may write it C_s. It should be noticed that the steepest point or point of inflection in (F) does not necessarily occur at the 50 % selection point. The observational curve agrees with the calculated curve for Todd's figures almost exactly from about 30 % to 100 % but below 30 % the two are somewhat divergent. C_s may conceivably vary from 0 %, when no fish "exposed to risk" of capture by a net escape capture or when all of them escape capture, to a maximum value of 100 %. With a net giving this figure no fish at a particular centimetre measurement will be taken, while at the next centimetre measurement, all will be taken. This does not mean necessarily that selection is "knife-edged", but that with measurement of fish correct only to the nearest centimetre, there is no observable selective variation.

If now in addition to C_s and the position of the mode we can by a rigid method deduce the 50 % selection point and also the 25 % and 75 % selection points on the percentage curve we shall be in possession of a set of constants which may serve to describe the selective action of any net, and which are directly comparable with the corresponding constants calculated from the data for any other net. It is first necessary to calculate the area and Standard Deviation of the difference curve (E) for the net in question, but these are themselves useful for comparative purposes. If the net follows the "Law of Chance Selection"



(Wollaston, *loc. cit.*) the area will be equal to 100. The discrepancy of the area from 100 shows just how far the net fails to follow the "law". A net having all its meshes held open might be expected to follow this "law" more closely than one of which many of the meshes are closed up, are not acting in a selective manner. The calculation of the further constants mentioned for Todd's Beam V Figures is set forth on page 307. The descriptive constants for the "Beam V" experiments for the "Beam I" experiments and for the Gelder data are given in the following table:—

	Todd. "Beam V"	Todd. "Beam I"	Gelder
Coefficient of Sharpness	30.42	30.35	53.85
Steepest Point or Point of Inflexion	14.17 cms	11.1303	17.2843
% Retained at P. I.	59.05 cms	62.91	52.793
25 % Retained at	13.12 cms	—	16.696
50 % Retained at ("Position")	14.37 cms	11.185	17.2312
75 % Retained at	15.22 cms	12.09	17.722
Area of △ curve	81.434 %	69.896	89.66
Standard Deviation of △ curve (σ)	1.068 cms	.917 cms	.6643

The curves on p. 302 are the calculated ogives for the selection of the different cod-ends mentioned. Curve A is that of Todd's "Beam I" data, curve B pertains to Todd's "Beam V" data, curve C refers to Gelder's data from the brochure. Some of Gelder's percentages are incorrectly given. Those for 15, 17 and 19 cms. should be 93 %, 62 % and 3 % respectively, to the nearest unit. The corrected figures have been used here. The diagram in the brochure is quite incorrectly drawn and gives the impression that the selection is more sharp than it actually is, the white sections of the columns above 14, 15 and 16 cms. being much shorter than they should be, while the shaded part at 18 cms. is too long. In our curves A, B, C and D, the crosses represent points from the data, and the calculated mode is shown by a line with ends at right angles. Curves B and C represent the data very well from 25 % upwards, but curve A does not extend as far downwards as 25 %. Curves representing the end points of the data much better than those shown may be calculated by taking more than three points in the △ curve and fitting a Curve of Error to these. It will not in general represent the central parts of the selection data, the important parts, nearly so well as the 3-point curve, since the latter gives an ogive actually passing through

four points of the data. The curve in broken line at B is drawn from a 5-point △ curve and represents the extremes of the data well but not the central figures. On comparing the selection constants of the cod-ends, Gelder and Beam V, we find that the former net is very much sharper in selective action than the latter (C_s = 53.85 and 30.42), that the Gelder net follows the Chance Law much the more nearly (Area = 89.66 and 81.434, Percentage at Mode = 59.05 and 52.793). The Sharpness in selection of the Beam I and Beam V cod-ends is almost exactly the same (C_s = 30.42 and 30.35); the Beam V figures, however, follow the "Chance Law" much better than the Beam I figures. Thus, fitting a cod-end with one ring has not increased sharpness of selective action but has given selective action freer play. The most remarkable result, however, is the raising of the "position" of the selection curve in the Beam V figures by about 3 cms. compared to those for Beam I. It appears thus that the shape of a fully stretched mesh is not the ideal shape for allowing the escape even of flat fish; probably some of the meshes of the Beam V cod-end were ideally shaped for letting out the largest possible plaice. The Gelder curve lies well above the Beam V curve in "position" but it must be remembered that the meshes were 5.6 cms. and 8 cms. long respectively. If the "position" of the Beam V curve be raised in the proportion 8:5.6 the curve will lie as shown at D, that is to say far above the Gelder curve. Thus a cod-end supported by one ring should release far more small fish than a Gelder cod-end, if the meshes of the latter are arranged as in the experiments given. The meshes are probably much too square to give the best result with plaice, and if enlarged to give a result equal, in the saving of small fish, to the one-ring cod-end, a large proportion of marketable round fish would escape. Obviously, the Gelder cod-end would give a much better result if the meshes were held at a longer diamond shape. Then, the "position" of the curve might be expected to coincide with that of the one-ring cod-end, while the much greater selective sharpness of the Gelder would make it an ideal instrument for the release of young fish while avoiding the loss of those of marketable size. The long shape of the mesh too might avoid the loss of many marketable round fish. In conclusion we may say that the Gelder cod-end as constructed for the experiments discussed in the brochure gives a slightly better result in saving undersized plaice than an ordinary cod-end of similar mesh and probably not so good a result as a cod-end supported by one ring, but that modification of the shape of the meshes would probably render the Gelder a much more efficient "savings-gear" than either.

Note on the Method used in this paper.

It will be noticed that the curve calculated by the adopted method fits well the data from a point, varying from about 10 % to 30 %, to the upper limit of the data, but fails to describe the low percentages. A "4-point" ogive taking in a lower percentage point than the lowest we have used fits the lower data well but fails with the upper ranges, giving percentages of over 100, which is objectionable.

The "Law of the Mesh" seems to be a continuous function in the upper ranges of fish sizes upon which it acts but below a certain point it is discontinuous and an ogive asymptotic to an y-value much exceeding zero would seem to express as well as any other curve the fact that there is a very good chance of a fair percentage of fish, however small in size, being taken by a net. Thus, from the "Beam V" figures, we see that 16 % of plaice of 8 cms. failed to pass through the cod-end, and this figure lies very near the corresponding point on the ogive. It would probably be impossible to find a curve that would express properly the immense variations in "Catchableness" of fish of small size. We can only hope to express the continuous part of the data well by any mathematical curve and we may regard the lower limit of the ogive as giving a maximum percentage caught for fish below a certain size.

In cases where the sharpness of selective action of a net is not sufficient for a curve through 4 points on the corresponding ogive to express its character well, it is preferable to "blunt" the precision of measurement by combining the numbers at pairs of adjacent centimetres rather than to fit a curve near more than 4 ogive points. This method suggests itself for instance in connection with Todd's "Beam I—IV" figures for whiting and seems preferable to any more artificial method of "smoothing" the data. According to the suggested method the figures for say, 12 and 13 would be combined, and similarly those for 14 and 15. The resulting points would be at 12.5 and 14.5 or, with .5 cm. correction for the average error of .5 cm. in measuring, at 13 and 15.

A curve through the combined points at 12, 14, 16 and 18 cms. would express the selective action in the case in question quite satisfactorily.

Showing Calculation of the Coefficient of Sharpness of Selection $C_{(s)}$ and its Position.

Fish at cms	(A) % caught	(B) Differences of A.	(C) Logs of B	(D) Calculated from Curve	(E) Antilogs	(F) A Calculated
8	16	..	..	..	..	..
9	7	..	..	..	..	..
10	9	..	..	<0	<1	..
11	8	8	..	.1265	1.3	18.7
12	16	13	..	.9526	9	20
13	29	25	$1.3979 = y_{-1}$			29
14	54	29	$1.4624 = y_0$	same	same	54
15	83	14	$1.1461 = y_1$			83
16	97	1		.4490	2.8	97
17	98	2		<0	<1	99.8
18	100	..		..	..	100

$$a = y_0 = 1.4624$$

$$b = \frac{y_1 - y_{-1}}{2} = -.1259$$

$$c = \frac{3(y_1 + y_{-1}) - 2(y_1 + y_0 + y_{-1})}{2} = -.1904$$

$\therefore$ Equation is $y = 1.4624 - .1259\ x - .1904\ x^2$

$$\text{Mode} = \frac{-b}{2c} = -.33$$

x_0 is 14.5 cms., $\therefore$ mode is at $14.5 - .33 = 14.17$ cms.

The highest ordinate (Y_0) is obtained by substituting $x = -.33$ in the equation.

$$\text{Thus } Y_0 = 1.4624 - .1259\ (-.33) - .1904\ (-.33)^2$$
$$= 1.4624 + .041547 - .02073456.$$
$$= 1.48321244.$$

Antilog $Y_0 = 30.42 = C_s$.

Showing Calculation of Percentage Points etc.

Equation (D) is $y = 1.4624 - .1259\,x - .1904\,x^2$

$$c = .1904.$$

Multiply c by 2.3026 to reduce it to a natural logarithm (to base "e")

$$c \times 2.3026 = 438415 = c_n.$$

The standard duration $(\sigma) = \sqrt{\frac{1}{2c_n}} = 1.068$ cms.

Area of (D) curve $= y_0 \sqrt{\frac{\pi}{c_n}} = 81.434.$

We now find the value (%) at the Point of Inflexion, at 14.17 cms. as follows:—

From 14 cms. to the mode is .17 cms. This in terms of σ, namely $\frac{x}{\sigma} = .159.$

Find (from PEARSON's Table II[1]) or any table of Curve of Error areas) the area between $x = o$ & $x = .159$. In PEARSON's Table .5 is added to all areas.

Area is .062 approx. (.562 in PEARSON)

$.062 \times 81.434 = 5.05.$

Ordinate at 14 cms. is 54

$\therefore$ Ordinate at mode (14.17) is $54 + 5.05 = 59.05.$

Area between 59.05 & 50 is 9.05.

9.05 as % of area (81.434) is 11.1, or .611 for the Table.

From Table II this corresponds to $x = .282$ approx.

$.282 \times 1.068 = .3.$

50 % point is thus at $14.17 - .3 = 13.87$

— — — — —

Area between mode & 25 % pt is $25 + 9.05 = 34.05.$

This as percentage of 81.434 is 41.8.

x from Table II is 1.395.

$1.395 \times 1.068 = 1.4898$

$14.17 - 1.4898 = 12.68$

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[1]) PEARSON. Tables for Statisticians etc. Cambridge University Press.

Area between mode & 75 % pt is 75—59.05 = 15.95.
This as % of 81.434 is 19.6 (.696 for Table)
x from Table II is .515
.515 × 1.068 = .55
14.17 + .55 = **14.72.**
Discrepancy from "Chance" Law = 100—81.434
= 18.566 %.

To obtain the true sizes at which 25 %, 50 %, and 75 % were retained, .5 cms. must be added to allow for the average error of .5 cms. in measuring the fish.

The sizes are thus:—

for 25 %.....13.18
- 50 %.....14.37
- 75 %.....15.22

The uncorrected figures are given in the table and used for drawing the curves since it simplifies matters and avoids the necessity for interpolation, to regard fish of between "n" cms. and "n + 1" cms. as "n" cm. fish.

On the unusual Mortality amongst Fish during March and April 1929, in the North Sea.

By

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Ministry of Agriculture & Fisheries, Lowestoft.

Shortly after the exceptionally cold spell in the early months of the present year (1929), the Lowestoft fishermen began to discuss amongst themselves a number of unusual experiences affecting their industry. For example, the distribution of some of the food fishes seemed to be unusual, and there were noteworthy occurrences of less common fish. Mention was made of the relative abundance in the waters off the Continental coast of numbers of small sturgeon, and the increase in the number of flounders caught was also commented upon. Doubtless the presence of these fish in the open sea was connected with the arctic conditions prevailing on the Continent, the fish having been driven out of the rivers by the cold. The distribution of the Sole (*Solea vulgaris*) was certainly abnormal, and this feature is described in more detail below.

But the most remarkable experience, and the one which forms the subject of the present paper, was the large number of dead and decaying fish which were found in the catches during March and April this year.

Apart from the fact that, under ordinary circumstances, the majority of fish taken by the trawl are dead or dying when brought on board, an occasional fish is found which has obviously been dead for some time before being caught. On the occasions to which we refer, considerable numbers of fish, chiefly soles, were brought on board in a state which shewed that they had been a comparatively long while dead. Many of the soles affected in this way could be detected by numerous white, sore patches on their upper surfaces, as well as by the chafed condition of the skin. Not in-

frequently, however, these dead fish were not distinguishable at first sight, and closer examination was needed. It may have been that whilst in the water the unusually low temperature had the effect of maintaining the outward appearance of the fish more or less normal, and that exposure to higher temperatures on board soon made it evident that the fish were decaying. The true state of affairs was not made evident to one crew, for example, until they attempted to cook some of these fish — an effort attended by discomfort on the part of the ship's company generally. In consequence, the crews soon grew aware of the necessity of distinguishing carefully between these unwholesome fish and those which had entered the trawl alive. No opportunity was afforded to us of examining any of these fish, but Dr. J. J. Tesch, s'Gravenhage, has kindly informed us, and permitted us to say here, that he had seen some of the soles affected, but was unable to attribute their condition to any particular cause.

After the first casual remarks, the reports became so frequent that steps were taken to collect as much information as possible bearing on this phenomenon, for which there is apparently no precedent on record for these waters at least. Of course, there was at that time some natural anxiety on the part of those connected with the fishing industry lest the presence of these dead fish in the catches should become generally known, since the knowledge might have affected adversely the public demand for fish. It was therefore necessary to avoid any action which would have drawn undue attention to the matter. Sufficient information was nevertheless obtained at the time of the occurrence to put it beyond doubt that there was an abnormality in the presence of these dead fish in the catches, and that their number must have been considerable.

The reports were first received early in March, and they continued to be received until towards the end of April. After this time, these fish either disappeared or their numbers fell so low as to call for no further comment.

As regards the numbers of the dead fish, one report stated that, during March, 15 boxes of soles (according to the skipper's estimation) were thrown overboard in the course of one trip lasting about a week. That is to say, about 15 cwts., or 750 kilos, of fish were so dealt with. Two other reports mention that occasionally after a haul as much as two baskets of dead fish were disposed of as unfit for market. This would be about $^3/_4$ cwt., or nearly 40 kilos, of fish. These figures are, of course, far too rough to serve as an adequate basis for a quantitative estimation of the destruction of the fish stock, but they indicate that the extent of the damage cannot have been inconsiderable on the particular grounds affected. According to the Ministry's statistical returns, English steam

trawlers landed 223 cwts. of soles in March 1929 from rectangle J6, which more or less coincides with the Terschelling ground, the region evidently most affected. The corresponding average catch (considering soles landed) per 100 hours fishing is 6 cwts.

In addition to the Sole, other kinds of fish mentioned as having been destroyed are Brill, Cod, Conger, Dab, Plaice and "Miller's Thumb" (Cottus). According to the information kindly transmitted to us by Dr. Tesch, the Dutch fishermen found a number of dead crabs on the eastern grounds, in addition to other fish (also chiefly soles). A few dead crabs were taken by an English boat on the Shipwash ground.

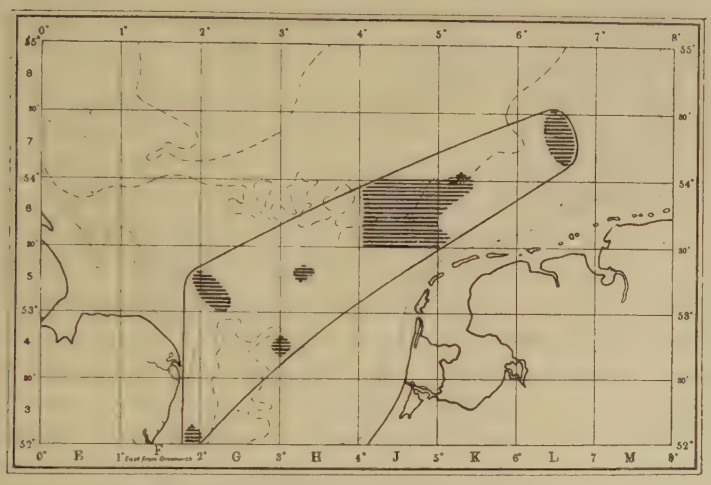

Chart 1. The region to which reports apply of dead fish taken in the trawls during March and April 1929.

The majority of the reports, especially the earliest, referred to the neighbourhood of the Terschelling ground (rectangle J6). The experience of the Dutch and English fishermen is quite the same in this respect. (In addition, Dr. Tesch refers in his letter to grounds situated in rectangle L7, slightly further to the North-east.) It seems therefore to be this region in which the mortality originated. Later on, a few reports were received relating to more westerly grounds such as the Shipwash, Well Bank and Winterton Gut. Dead cod were taken in Tea Kettle Hole. The inference from this apparent extension is that either the conditions which caused the mortality spread to the South-west, or the dead fish were transported there by the currents. On hydrographic grounds, the latter explanation is the more probable, as will be seen later. It may be mentioned here, however, that according to the Drift Indicator mea-

surements at the Varne Lightship[1]), there was a marked reversal of the normal (NE.-going) direction of the flow through Dover Straits during the whole of the first week of March, and from then until the end of April the flow was mainly abnormal, being either towards the NW. or occasionally reversed from the usual direction.

The area — some 200 miles long and, in the middle, 50 miles wide — from which the dead fish were reported to have come is shewn in Chart 1. It more or less covers the grounds on which the Lowestoft steam trawlers are usually working at that time of the year, and since, as has already been mentioned, the bulk of the reports originated from Lowestoft boats (in addition to the Dutch and a few from Grimsby), the question arises as to whether a similar mortality may not have affected other regions of the North Sea. Furthermore, it would be natural to report an experience such as the occurrence of large quantities of dead fish in the catches, but skippers would not be likely to mention their absence, since there is nothing unusual in this upon which to comment. To obtain negative observations, therefore, enquiries had to be made, and their result tends to confirm the conclusion that the phenomenon was limited to the area shewn in the chart. We are indebted to Mr. R. Burton, of Hull, for the information that, of the two fleets controlled by his firm, the one working to the south-eastward in the Helgoland Bight, reported the presence of the dead fish, while the other fleet working further North, in about Latitude 56° N., made no comment on this matter. Incidentally, the report of the southern fleet contained the information that the fish affected (kinds not specified) were small. Reports were obtained from two of the Ministry's sea-going staff working from Grimsby as to their experiences of this matter during March and April. It is evident from the one report that the phenomenon was not encountered. The rectangles which in this instance yielded definitely negative observations are as follows:— C11, 12; D8; E7, 8; F6, 7; G5, 6, 7; H5, 6. Although voyages were made by this observer in the area within which the dead fish were found, it is significant that no voyage took place actually in rectangle J6, *i.e.*, in the area in which the mortality was most pronounced. The second observer stated that considerable numbers of dead fish had been seen, and in this instance the Terschelling ground was fished. The rectangles visited were:— E7; F6, 7; G4, 6, 7; H4, 7; J6, 7; K7. Moreover, this report adds that very few dead soles were found on the grounds between Grimsby and the Dogger Bank.

The reason for this destruction of fish is generally assigned by the

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[1]) For this information I am indebted to Dr. J. N. Carruthers. J. R. L.

fishermen to the intense cold. Though this explanation, which is at least probable, may be true, there is a lack of fully decisive evidence as to the causes. The occurrence is perhaps analogous, no doubt on a smaller scale, to the case of the Tile-fish, which was destroyed in enormous quantities off the Grand Banks of Newfoundland in the early part of 1882. The cause of this was thought to be the sudden arrival of cold water on the grounds which the fish normally inhabited. Besides the Tile-fish, it was found that other kinds of fish had been similarly affected at the same time, and Professor VERRILL[1]) remarked on the scarcity or even absence from the sea-bottom "of many of the species, especially crustacea, that were taken in the two previous years, in essentially the same localities and depths, in vast numbers, several thousand at a time". In another paper which deals with the catastrophe to the Tile-fish, Captain COLLINS[2]) mentions a number of other similar, earlier instances, the reports of which, either on account of the smaller scale or of insufficiency of evidence, attracted less attention. Dead cod were seen floating in large numbers off the coast of Labrador in 1876, and in December 1789 a ship is said to have passed through "immense quantities of dead haddocks" off the coasts of Lapland and Norway. And other examples of similar sudden destructions of fish are referred to. Occasions of fish being destroyed in shallow, inshore waters by sudden frosts (or sometimes excessive heat) are not infrequent, and we may illustrate this by the following quotation[3]) relating to an occurrence which took place this year in the neighbourhood of the Baltic entrance to the Kiel Canal. "Nun war in diesem Winter, bei dem plötzlich strenge auftretenden und anhaltenden Frost in Verbindung mit niedrigem Wasserstand den Fischen die Gelegenheit genommen, rechzeitig tieferes Wasser zu erreichen. Sie sind, da teilweise das Eis bis auf den Grund reichte, erfroren. Die Fische und vor allem Plattfische, Aalquappen usw. liegen jetzt in Massen tot auf dem Grunde. Auch bei grosser Wärme sind die Fische übrigens in ihrem Fortbestand in diesem abgeschlossenen Gewässer ständig bedroht."

So far as they go, these examples point to the conclusion that the changes in environment which give rise to such phenomena must be

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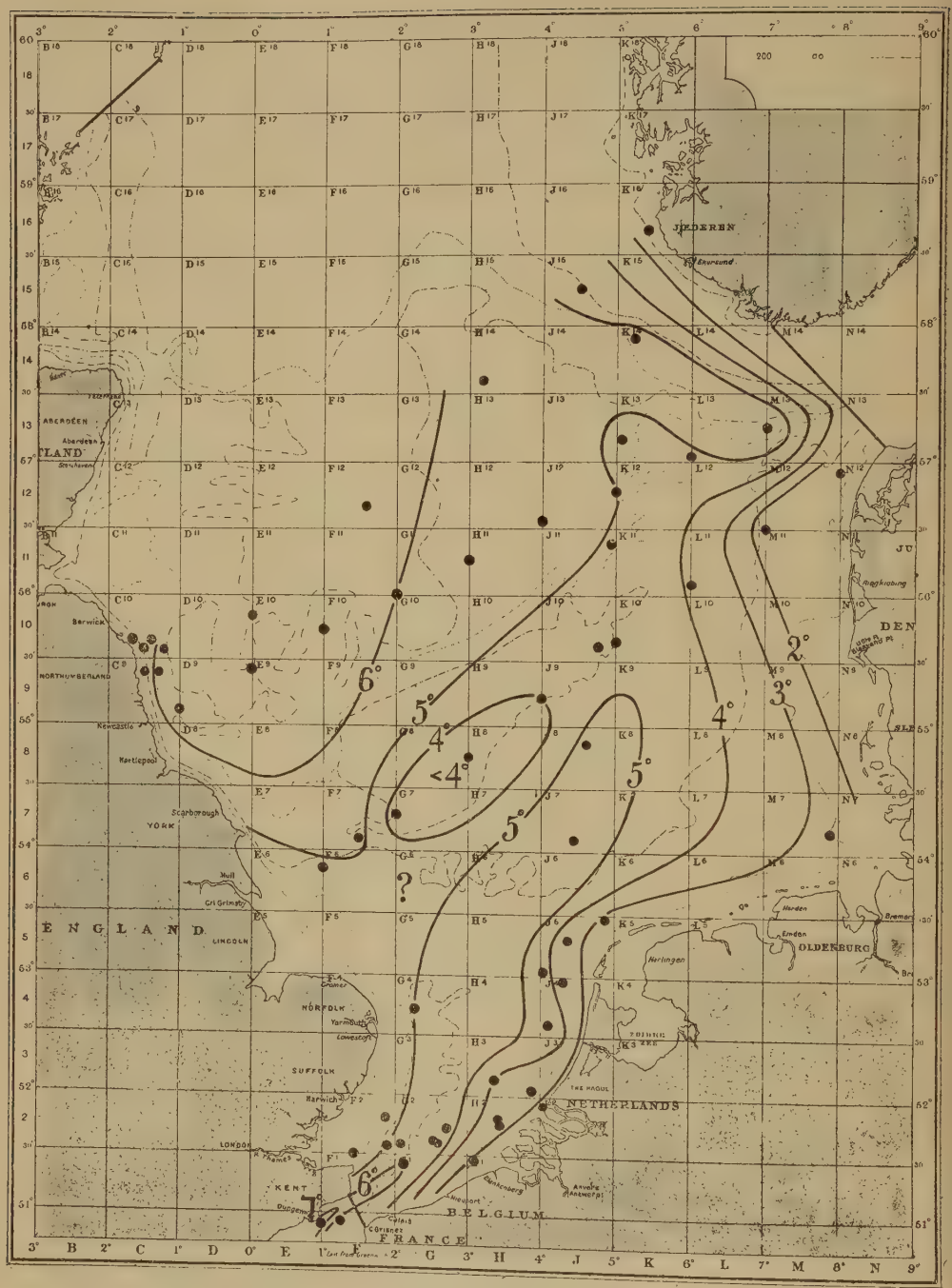
[1]) Quoted from H. C. BUMPUS. The Reappearance of the Tile fish. Bull. of the U. S. Fish. Comm. Vol. XVIII for 1898. Washington 1899.

[2]) J. W. COLLINS. History of the Tilefish. U. S. Comm. of Fish & Fisheries. Part X. Report of the Commissioner for 1882. Appendix B, XI. Washington 1884. p. 275.

[3]) H. SCHNOOR. Vernichtung von Nutzfischen der Ostsee durch den strengen Winter. Mitt. d. deutschen Seefischerei-Vereins. Bd. XXXXV. Nr. 5. Berlin 1929.


6°
5°
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?
ENGLAND
FRANCE
BELGIUM
NETHERLANDS
DENMARK
JUTLAND
OLDENBURG
NORTHUMBERLAND
YORK
LINCOLN
NORFOLK
SUFFOLK
KENT
LONDON
ABERDEEN
Aberdeen
Berwick
Newcastle
Hartlepool
Scarborough
Hull
Gt Grimsby
Yarmouth
Lowestoft
Harwich
Dunkerque
Calais
Ostend
Antwerp
Flushing
Helder
Harlingen
Emden
Bremen
Esbjerg
Skagen
Frederikshavn
Aalborg
Thisted
Hanstholm
Skudesnaes
Egersund
Farsund
Lindesnaes
Kristiansand
Arendal
Skagerrak
Kattegat
The Hague
Ijmuiden
Texel
Vlieland
Terschelling
Ameland
Schiermonnikoog
Borkum
Norderney
Juist
Langeoog
Spiekeroog
Wangerooge
Harlingen
Terschelling
Vlieland
Texel
Ijmuiden
The Hague
Rotterdam
Hook of Holland
Flushing
Ostend
Dunkerque
Calais
Boulogne
Le Touquet
Berck
Le Crotoy
St Valery
Dieppe
Fecamp
Le Havre
Trouville
Deauville
Cabourg
Ouistreham
Arromanches
Port en Bessin
Grandcamp
Isigny
Carentan
Barfleur
Cherbourg
Omonville
Goury
Alderney
Casquets
Guernsey
St Peter Port
St Helier
Jersey
Les Minquiers
Les Ecrehos
Paternosters
Chausey Is
St Malo
Cancale
Granville
Pointe du Roc
Pointe de Grouin
Pointe de Penlan
Pointe de Pen-Men
Pointe de Pen-Bron
Pointe de Pen-Lan
Pointe de Pen-Ar-Bed
Pointe de Pen-Ar-Men
Pointe de Pen-Ar-Ven
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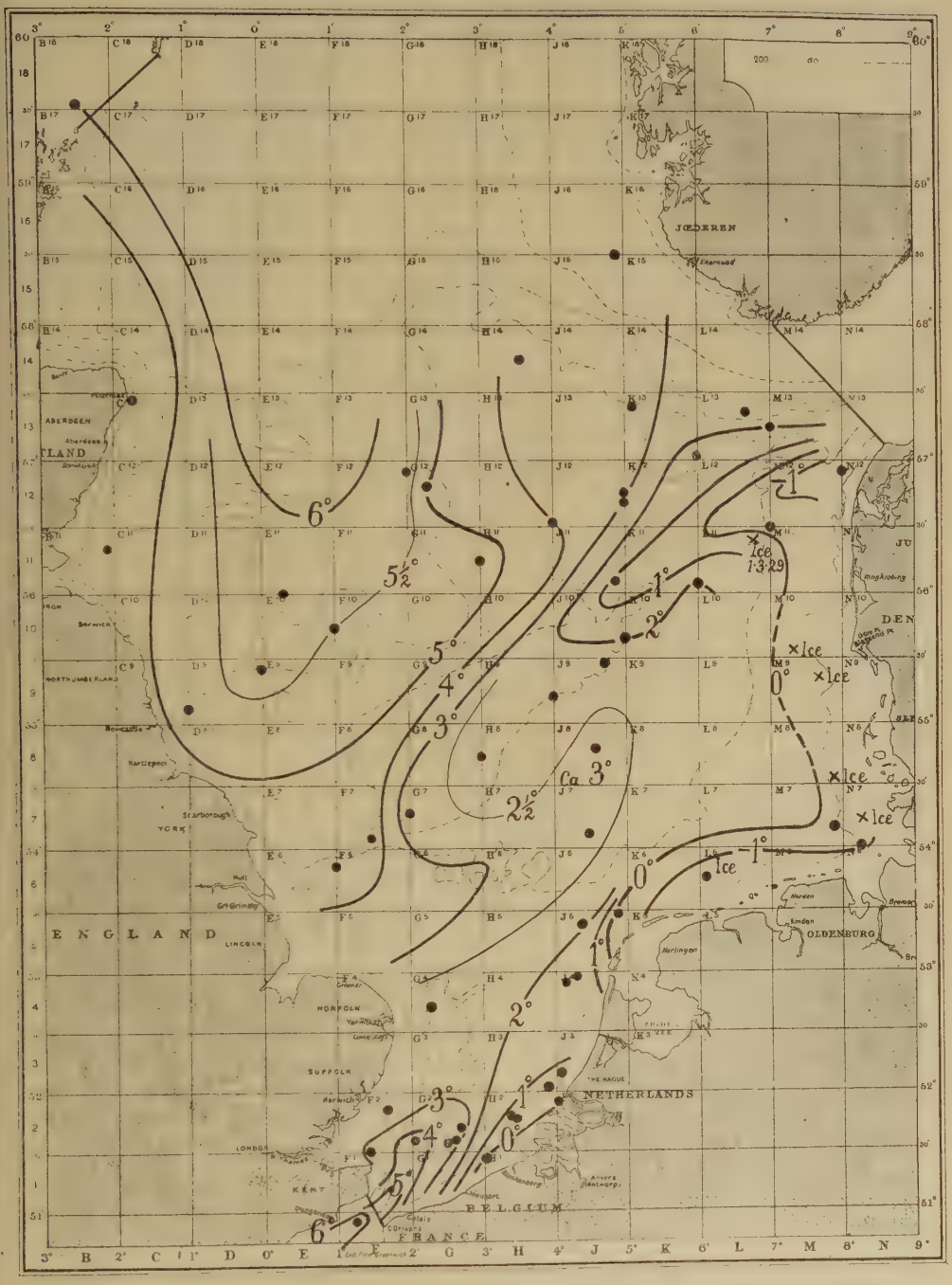

Chart 3. The distribution of surface temperature (°C) at the end of February 1929. The majority of the observations used were made between 22nd and 26th of the month.

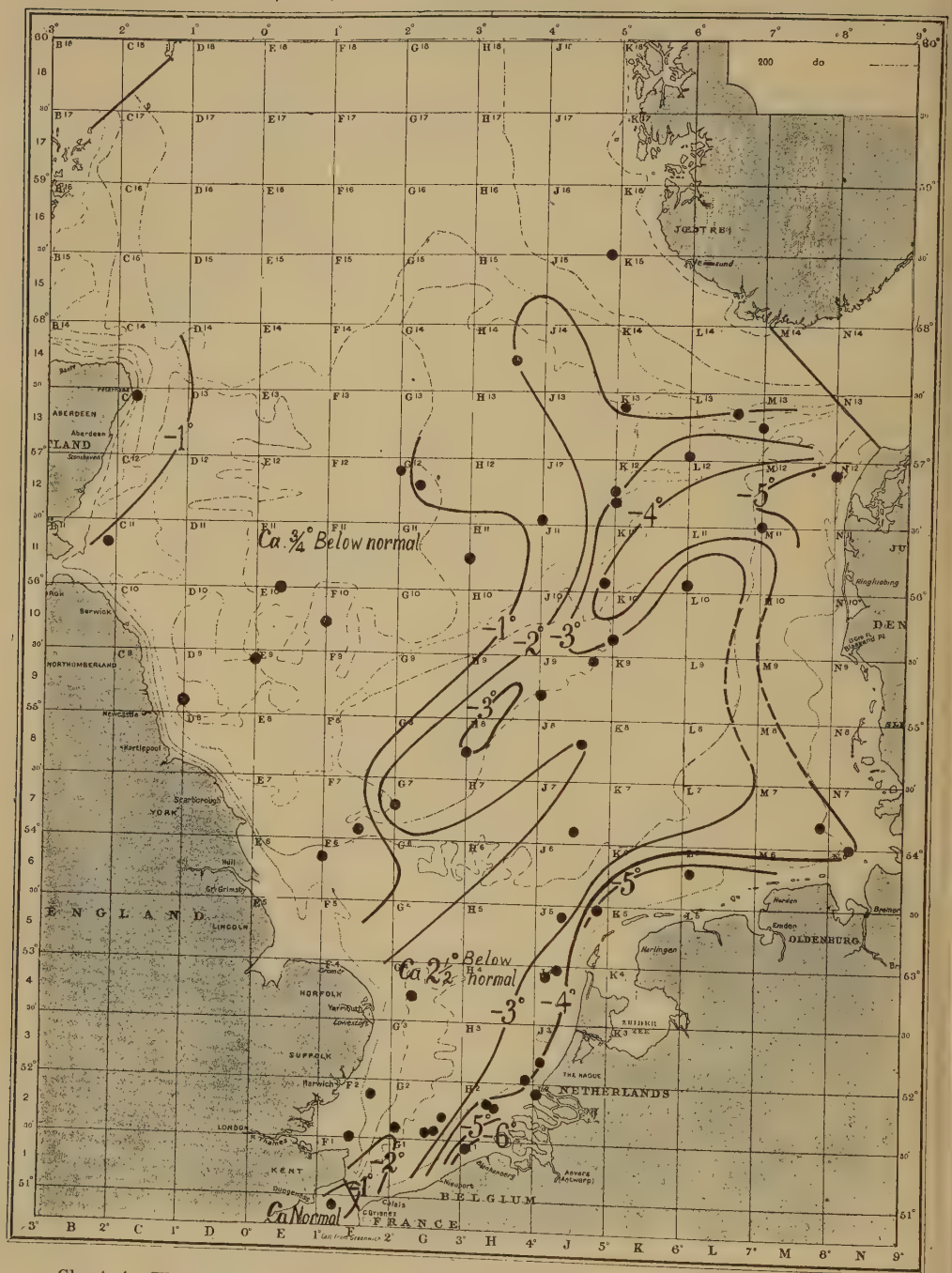

Chart 4. The deviation of surface temperature at the end of February 1929 from the means for February, period III, 1905—1914 (Bull. Hydrog.).

Chart 5. The distribution of surface temperature (°C) at the end of March 1929. The majority of the observations used were made between 21st and 25th of the month.

of a catastrophic nature, and we may assume that conditions must border on the exceptional. It is not conceivable, for instance, that all sudden changes of temperature could lead to a destruction of fish on the scale on which it took place this year.

In the present case, there is evidence that the conditions were so exceptional that they may have contributed to the mortality which we have described, the factor involved being the water temperature. Along the Continental coasts of the North Sea the temperature of the water fell very low during the early months of this year. Chart 3 shews the distribution of surface temperature at the end of February (for dates of observations used, see chart), at which time the water in the North Sea generally was about at its coldest. Chart 4 shews the deviation of this distribution from the normal. While the temperature of the water (about 5—6° C.), which extended well South along the Scottish and northern English coasts, and which was also to be found in Dover Straits, was not much removed from the normal, there was, along the eastern coasts as far as the Skagerrak, a relatively wide belt of water in which the temperature was below 0° C., being from 3° to 6° C. lower than normally. There was also a considerable quantity of ice along the North German and Danish coasts[1]). During the last ten days of February the Lightships "Horns-Rev" and "Vyl" were withdrawn on this account, as were also the Lightships "Amrumbank" and "Ausseneider" from February 12th to March 3rd. At this time, too, the "Borkum-riff" vessel was surrounded by drift ice. It is, further, worthy of mention that drift ice was reported at sea as far West as position (approx.) 56°25′ N. 6°40′ E. (in rectangle L 11). At this point we may draw attention to what is a striking peculiarity of the temperature distribution at that time, namely, the tongue of cold water extending south-westwards from the entrance to the Skagerrak well across the Dogger Bank. In our opinion the whole of this cold water was not derived from the Continental coast, nor did it come from the English side. Examination of the temperature observations on the Hull—Hanstholm route leads to the conclusion that, while cold water moved offshore from the Jutland coast as far as between Long. 5° and 6° E., — under the influence of the easterly winds then prevalent (see Table I) — the water over the shallow Dogger Bank, especially the south-western end, cooled more rapidly than elsewhere in the neighbourhood. An extension of the two regions of cold water, till a junction were effected, would then cause the isotherms to take on

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[1]) For these details we are indebted to the Deutsche Seewarte, Hamburg, and to the Danish Meteorological Institute, Copenhagen.

the form of the tongue seen in the chart. At the end of January, when the temperature was falling, the cold region over the South-West Patch is clearly shewn separated from the cold water off the Jutland coast (see chart 2). At the end of March, when the temperature had begun to rise, the former of these cold water regions was no longer so noticeable in the series of observations referred to (though see below).

For the rest of the southern part of the North Sea, including much of the Southern Bight, the temperature was between 2° and 3° C. at the end of February, the anomaly being about $2^1/_2$° C. below the normal for the time of year.

The effects of this especially rapid cooling over the bank had not, however, been entirely obliterated by the beginning of April, and that they do not appear definitely in the March chart is probably to be accounted for by the inadequacy of the data available. By the courtesy of the

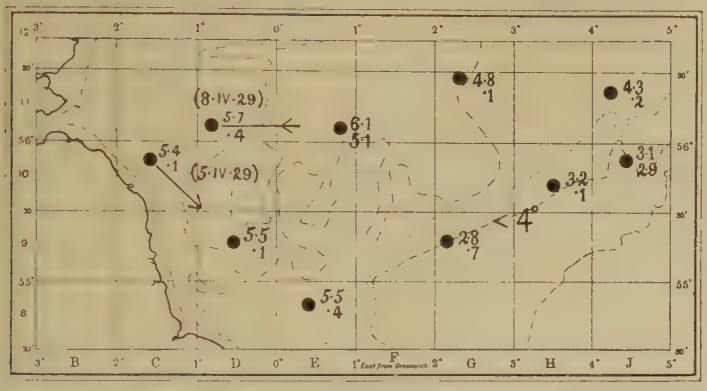

Chart 6. Temperature (°C) at surface and bottom, April 5th—8th, 1929.

Fishery Board for Scotland, we are permitted to refer to the results of a cruise undertaken by them between the 5th and the 8th April. The stations are given in Chart 6, which also shews the corresponding surface and bottom temperatures. Evidently this cold, heavy water previously found (as far as our data enable us to judge) mainly over the south-western part of the Dogger Bank was, by April, moving down the northern slopes of the bank into the deeper water.

Returning to the question of the tongue-shaped formation of the isotherms across the Dogger Bank at the end of February, examination of the charts (Nos. 7, 8 and 9) of salinity distribution for corresponding dates gives no indication of any exceptional water movements by which the cold water off the Danish coast could have been transported as far West as Long. 2° E. All three charts shew, more or less clearly, the three main streams (according to Böhnecke) of salter water running

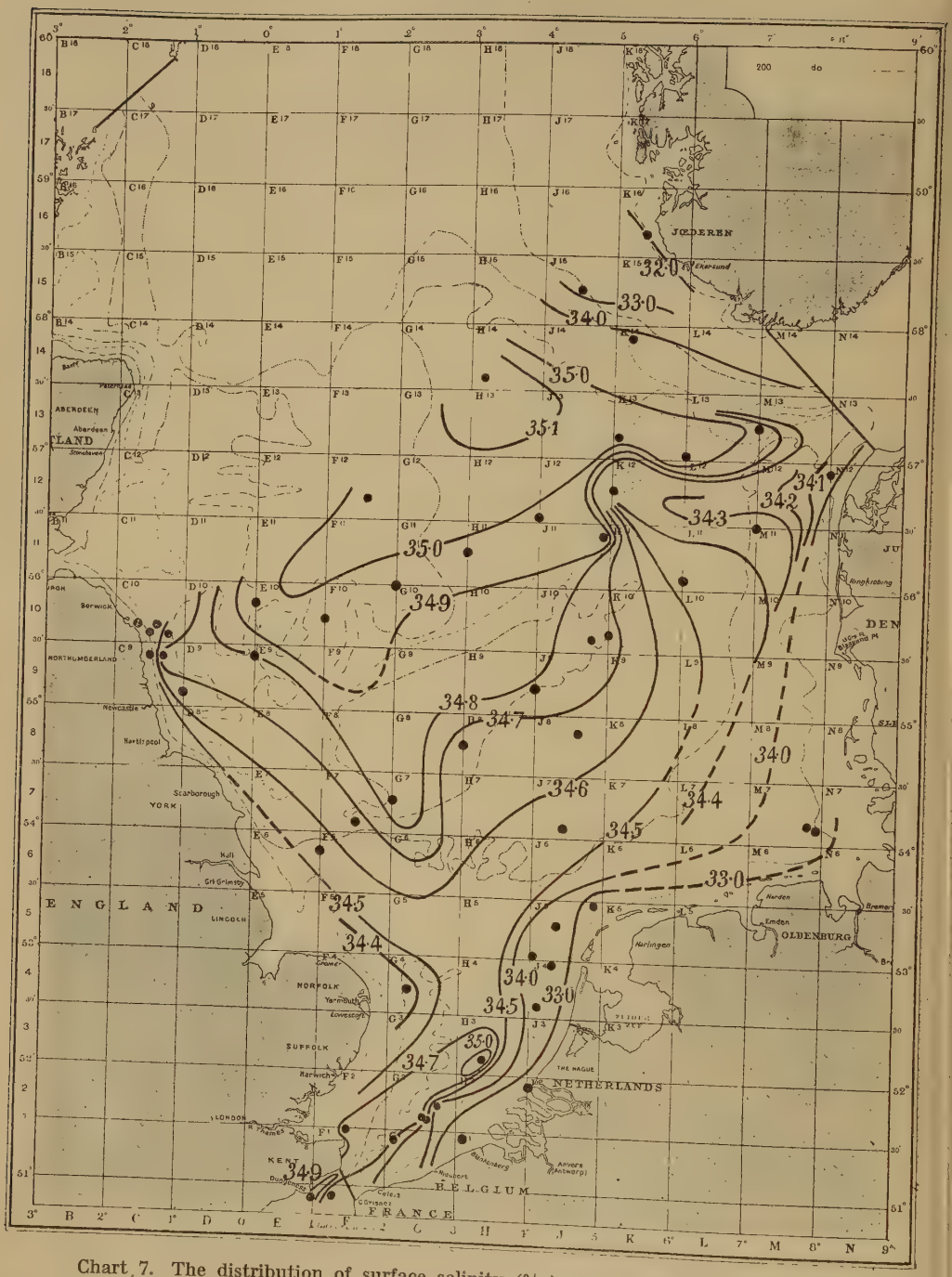

Chart 7. The distribution of surface salinity (‰) at the end of January 1929. (Corresponding with chart 2).

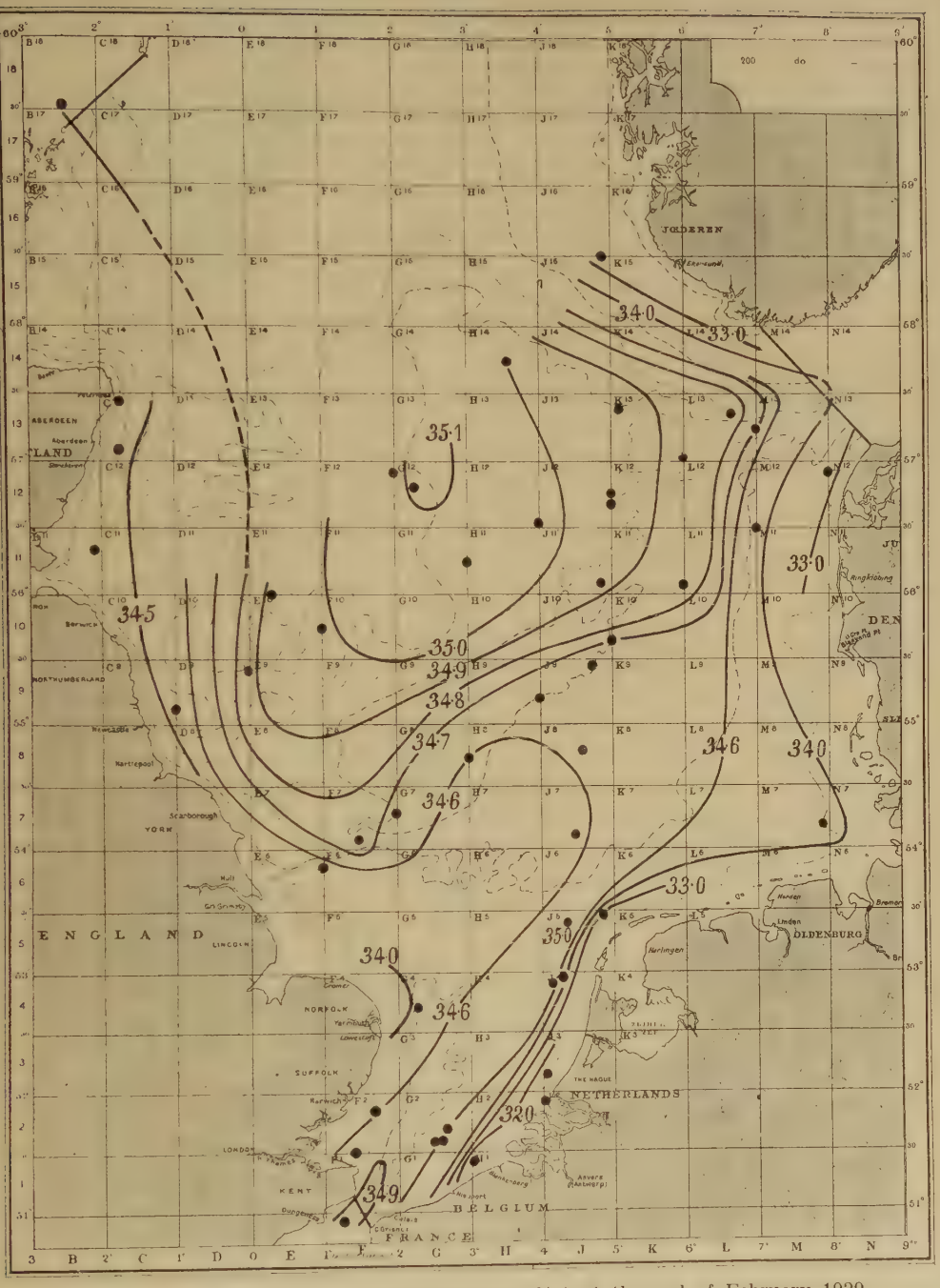

Chart 8. The distribution of surface salinity (‰) at the end of February 1929.
(Corresponding with chart 3.)

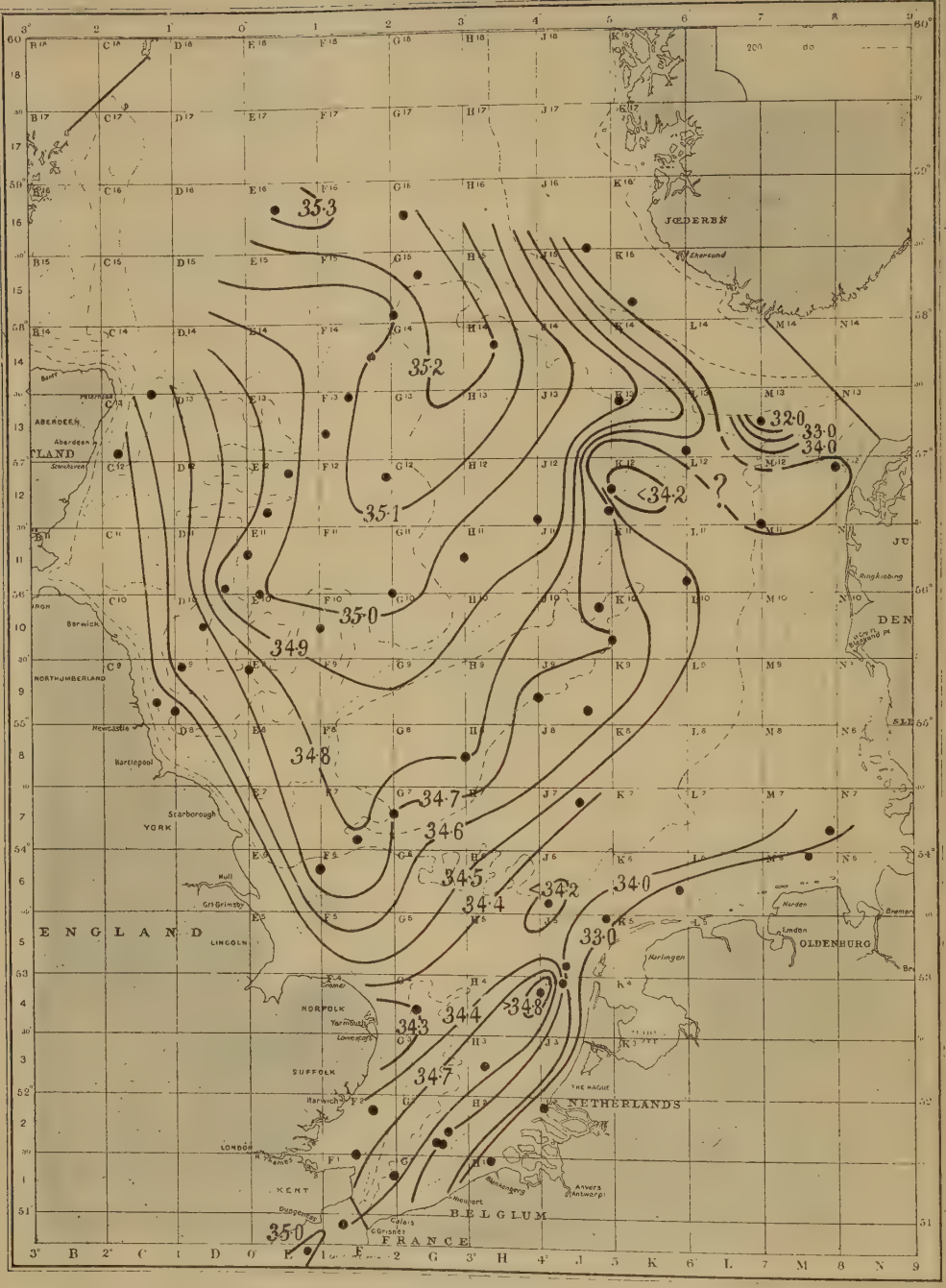

Chart 9. The distribution of surface salinity (‰) at the end of March 1929.
(Corresponding with chart 5.)

Table I. Residual Wind for 10-day Periods, 1929, (speeds in miles/hour and directions true) calculated (for Utsire & Blaavands Huk) from the Observations published in the Daily Weather Report (International Section) issued by the Meteorological Office, London; for Cromer Knoll, from the Observations made on board the Lightship 8 times a day[1]).

1929	Utsire	Blaavands Huk	Cromer Knoll L.V.
January I.....	2 m/h S 57° E	5 m/h S 84° E	9.1 m/h S 88° E
— II.....	9 - N 8° W	5 - N 15° W	7.3 - N 13° W
— III[a])	13 - S 28° E	4 - S 23° E	2.5 - S 34° E
February I.....	24 - S 29° E	10 - S 39° E	9.1 - S 8° E
— II.....	17 - S 72° E	6 - S 77° E	10.9 - S 51° E
— III[a]) ...	5 - S 29° E	(7 - S 53° E)[b])	8.5 - S 68° E
March I	8 - N 41° W	6 - N 52° W	2.3 - N 51° W
— II	4 - N 15° W	3 - N 38° W	1.8 - S 86° E
— III[a])	6 - S 53° W	6 - N 70° W	2.8 - S 71° W

a) From 21st till end of month.

b) Insufficient observations at Blaavands Huk. Bracketed value obtained from Hamburg observations.

South across the south-western end of the Dogger Bank, South-East across its north-eastern end, and finally East into the Skagerrak. *Vis-a-vis* the south-easterly winds which prevailed at the end of January and February (see Table I), the apparent normality of these salinity charts is striking.

Having briefly sketched the temperature conditions and demonstrated that they were so far abnormal in the region chiefly concerned, namely, the Terschelling ground, as to suggest that this factor might well have been a contributory cause of the mortality amongst the fish and other animals on that ground, we return to the second point, that of a sudden fall in the water temperature. For this purpose we are less fortunate in the data at our disposal. The requirements are observations of the temperature at the bottom in this region, and they are entirely lacking. In using surface observations for want of better, it must be remembered that though the water column at most parts of the southern North Sea is at all times well-mixed and practically homogeneous, close into the coast, especially that of Holland, coastal water occasionally overrides as a surface layer the salter, usually heavier water from the central regions of the Southern Bight. The greater part of the Terschelling ground is, however, sufficiently far removed from the coast to permit the use of surface observations for consideration of the conditions at

[1]) We are indebted to Dr. J. N. Carruthers for the use of the data from Cromer Knoll.

the bottom. To justify this, we may refer to the series of observations of the water column at the Dutch quarterly station H 1, the nearest position to the ground in question at which such data are available to us.

Table II. Analysis of the Differences (irrespective of direction) between the Temperatures (°C) and Salinities (‰) at Surface and Bottom (ca. 25 m.) at Station H1, 53°14′ N. 4°15′ E., calculated from the Quarterly Observations published in the Bulletins Hydrographiques, for February, May, August and November 1903—13.

Temperature °C.

Difference	0°	0.1°	0.2°	0.3°	0.4°	0.5° to 0.9°	>1.0°	Average Diff. 0.2°
No. of occurrences..	8	4	4	1	2	2	1	

Salinity ‰.

Difference	0	0.01	0.02	0.03	0.04	0.05 to 0.09	>0.1	Average Diff. 0.05 ‰
No. of occurrences..	7	1	6	1	2	2	3	

Of the 4 sets of observations in February, on three occasions the temperature was the same at surface and bottom, and on the fourth, the temperature was 0.2° C. higher at the bottom than at the surface.

The observations of surface temperature from mid-January to mid-March on the Stavanger—Rotterdam route, the positions of which fall within rectangle J6, are shewn plotted in Figure 1. For comparison, the 10-day averages of the Terschelling Lightship were also included in the graph, together with observations from Helgoland roads, both sets of data being derived from the proof sheets of the 1929 Bulletin Hydrographique. The three curves agree in shewing that a sharp fall of temperature occurred in the first half of February. The Helgoland observations, which are the more detailed, indicate a fall from + 1.7° C. to —1.4 ° between the 7th and 15th of the month. The temperature at the Smith's Knoll Lightship also dropped markedly at about the same time. It is, moreover, to be noted that the lowest value shewn for rectangle J6, on 11th February, was obtained at a position actually just outside its northern boundary (54°01′ N. 4°29′ E.), that is to say, at a position furthest removed, in comparison with the remainder of the observations,

from the influence of the very cold belt of coastal water. Furthermore, at this time very strong south-easterly winds occurred, which are likely to have had the effect not only of blowing the cold coastal water off

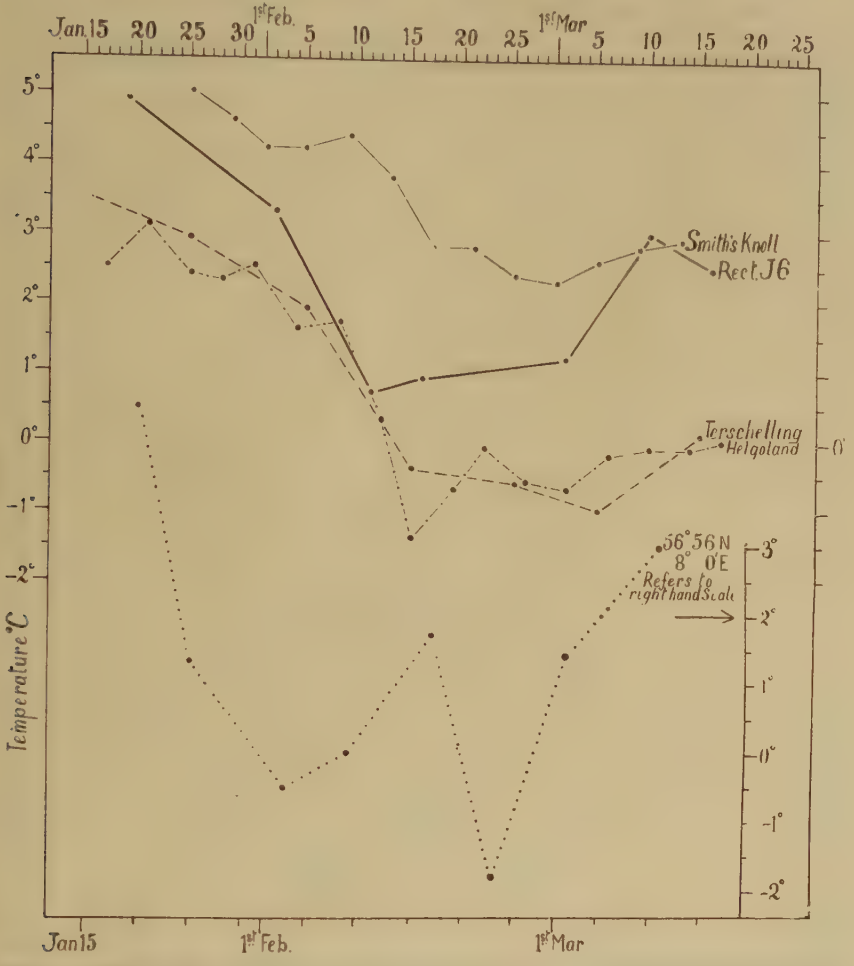

Figure 1. The surface temperature (°C) for rectangle J 6, Terschelling Light Vessel, Helgoland roads, Smith's Knoll Light Vessel, and position 56°56′ N. 8°0′ E. from mid-January to mid-March, 1929.

the Continental coast, out of the Helgoland Bight, but also of promoting vigorous mixture of the water column and thus lowering the temperature at the bottom. Such winds would obstruct the development of the swirl in the Helgoland Bight (see BÖHNECKE[1]) which, when present,

[1]) G. BÖHNECKE. Salzgehalt und Strömungen der Nordsee. Veröff. d. Insts. f. Meeresk. N. F., Reihe A. Heft 10. Berlin 1922.

tends to carry water eastward into the Bight towards Helgoland. In the absence of the swirl, westward movement of the water in the Bight is free to take place under the influence of the offshore winds.

The conclusion which, in the absence of completely decisive infor-

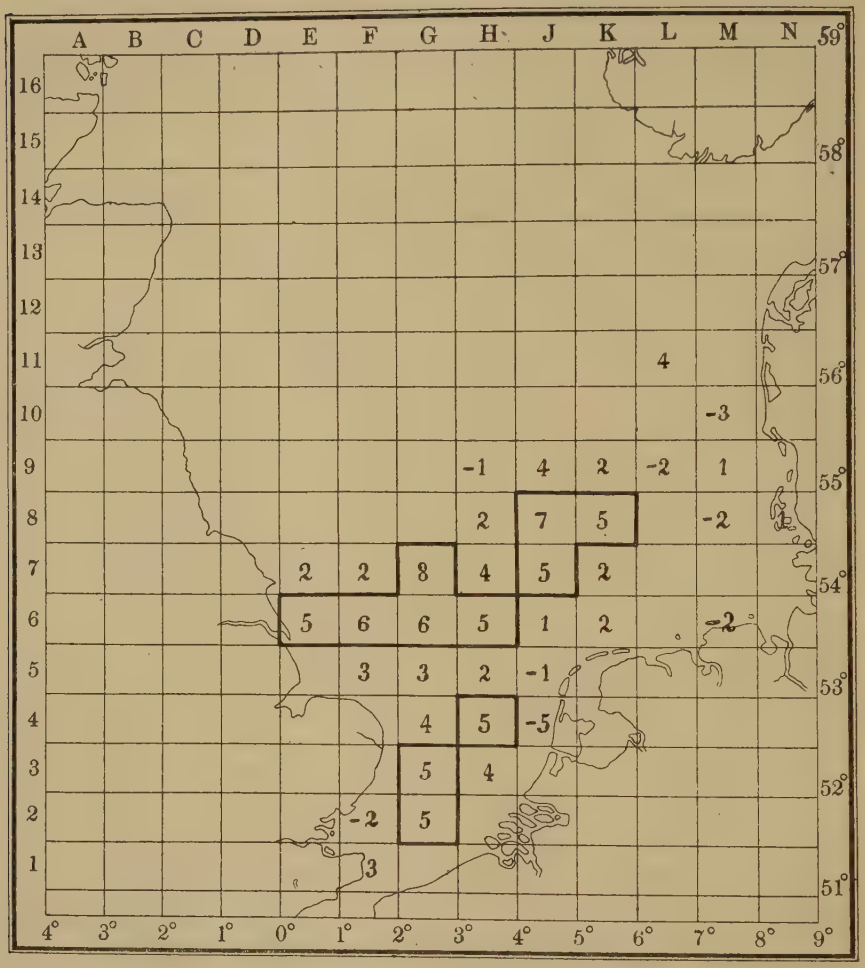

Chart 10. The deviation of the average catch of soles (cwts.) per 100 hours fishing in February 1929 from the mean for the same month over the period 1923—29 (incl.).

mation, we are entitled to draw from the foregoing evidence is that the conditions in regard to temperature were favourable for a sudden movement of abnormally cold water on to the Terschelling ground, and that, as far as the surface is concerned, such a movement appears to have taken place during the first half of February.

In the course of these investigations of the hydrographic conditions it must have become apparent that the Terschelling ground was by no means the only ground on which, judging from the existing state of affairs, the mortality amongst fish, as described above, could have been

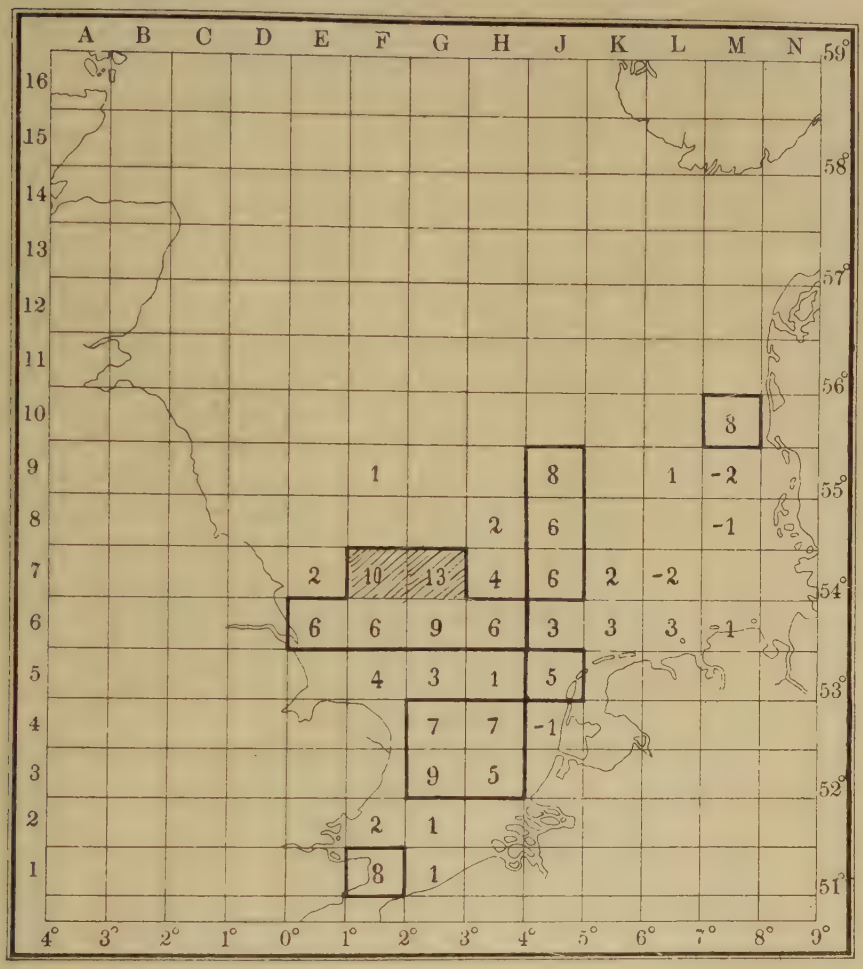

Chart 11. The deviation of the average catch of soles (cwts.) per 100 hours fishing in March 1929 from the mean for the same month over the period 1923—29 (incl.).

suffered. Equally sudden falls of temperature to very low values occurred elsewhere, particularly off the North Jutland coast. In Figure 1 is included a graph illustrating the surface temperature conditions at position 56°56′ N. 8°00′ E. There the temperature fell from +1.7° C. on the 17th February to —1.8° C. on the 23rd of the same month. Moreover, the

cold water with which this fall in temperature is associated, evidently moved a considerable distance south-westwards, as the temperature at position 56°5′ N. 6°0′ E. had become minimal at +0.6° C. on the 11th March (see observations on the route Hull—Hanstholm, Bulletin

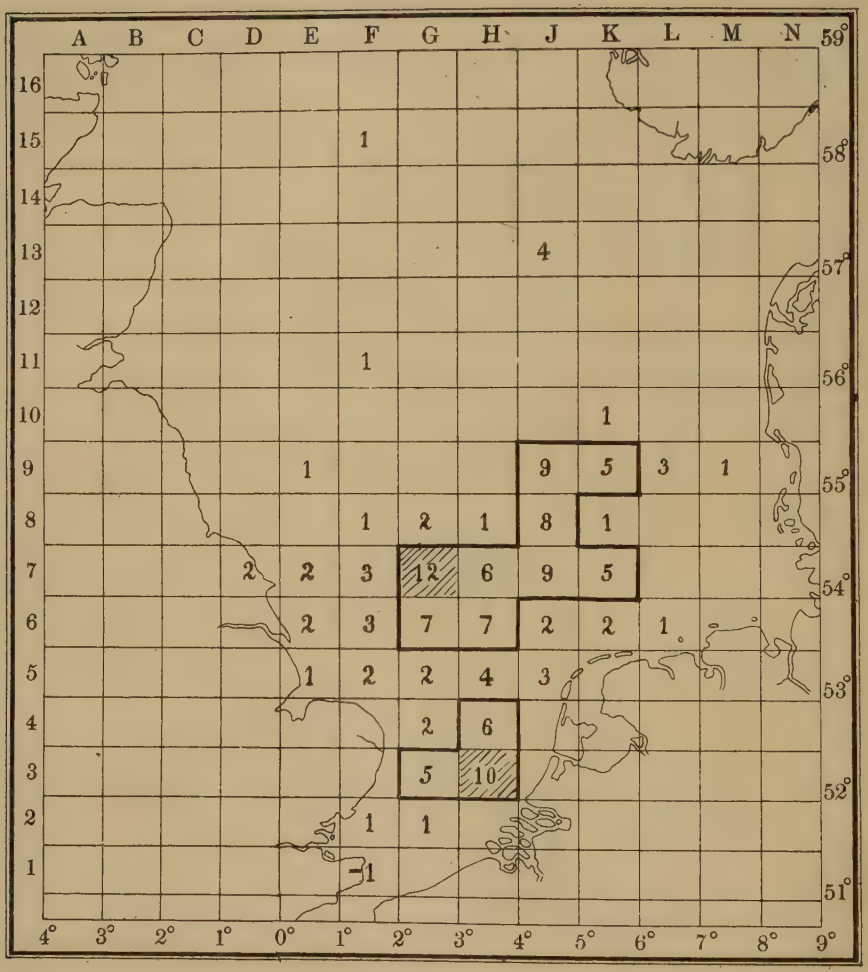

Chart 12. The deviation of the average catch of soles (cwts.) per 100 hours fishing in April 1929 from the mean for the same month over the period 1923—29 (incl.).

Hydrographique, 1929). There is, in fact, an excellent reason for the absence of reports of dead fish from this particular locality, namely, that little or no fishing was done there at that season of the year by the English vessels. Further to the South-west, however, where the intensity of fishing was not inconsiderable, low temperatures (though not below

1° C.) occurred as a result of the rapid cooling on the south-western part of the Dogger Bank. That they very soon reached the bottom, we are justified in assuming from the shallow nature of the bank, and that they eventually did so is confirmed by the Scottish observations referred to above. We have already ascertained, as far as the reports enable us, that no fish were killed in this region. Along the Danish coast the fishing was light, but it should have been sufficient to discover the existence of a destruction such as occurred on the Terschelling ground, yet the results of enquiries made tend to shew that fish in this region did not suffer the mortality.

It is of interest to examine, therefore, whether the influence of temperature can be traced in the distribution of soles over the North Sea generally. In Charts 10, 11 and 12 is shewn for each rectangle the anomaly from the mean of the catch of soles (in cwts.) per 100 hours fishing, reckoned from the Ministry's returns of soles landed by English steam trawlers, in February, March and April, 1929.

The means upon which the anomalies are based were calculated for the years 1923—1929 (inclusive). In order to provide, without shewing the actual mean charts which have been prepared, some idea as to the significance of the anomalies, Table III was drawn up.

Table III. Average catch of soles (cwts.) per 100 hrs. fishing (English steam trawlers) for the North Sea generally during February, March and April, in the years 1923—1929.

Year	February	March	April
1923	1 cwt.	0.9 cwt.	0.5 cwt.
1924	2 -	1 -	1 -
1925	1 -	0.5 -	0.3 -
1926	1 -	0.5 -	0.4 -
1927	1 -	0.9 -	0.5 -
1928	2 -	1 -	1 -
1929	4 -	5 -	3 -
Mean	1.7 cwt.	1.4 cwt.	1.0 cwt.
1929 less mean	+ 2	+ 4	+ 2

These figures shew that for the North Sea as a whole the average catch of soles per 100 hours fishing in these 3 months was more than twice as heavy in 1929 than in any previous year for which statistics are available, against which it may be recalled that the early part of 1929 was by

far colder than the corresponding seasons of any of the other years in the series.

The very much enhanced size of the catches may be confirmed by a casual inspection of the charts, since in the majority of the rectangles the anomaly is positive, *i.e.*, the catch was greater than usual. Closer examination of the charts reveals the fact that this abnormality is very much emphasised in three principal regions. The boundary lines of rectangles in which the catch per 100 hours fishing exceeded the mean by 5 cwts., and more, have been strengthened. The regions are quite clearly distinguished in all three months, and they may be broadly referred to the fishing grounds Clay Deeps (SE. of the Dogger), Silver Pits (SW. of the Dogger) and the "Deep Water" between East Anglia and Holland, in the Southern Bight. The exceptional intensity of the fishery in the Silver Pits and its duration over an unusually long period was a frequent subject of comment among the fishermen. In rectangle J 6, with which is associated the Terschelling ground, the seat of the heaviest destruction of soles, the catches were relatively very little above normal, though in the immediate neighbourhood, excepting only on the East, the anomaly was frequently above 5 cwts. per 100 hours fishing.

None of the grounds on which the catches were outstanding appears to be especially remarkable for its situation with respect to temperature distribution. Certainly the surface temperature (and, we may assume, the bottom also) on the grounds between the Humber mouth and the Dogger Bank, was, as an examination of the observations on the Hull—Hanstholm route will shew, constantly maintained at a comparatively high level by the flow of warmer water from the North. But the greatest anomaly is to be found, not in this region, but in rectangle G 7. This locality is intermediate between the cold region due to the rapid cooling over the shallows of the bank, and the warm water to the West. This water, it is to be noted, bends eastwards and northwards in the SW. Dogger Bank swirl. Similarly, the Clay Deep ground appears to occupy an indefinite position between the cold water due in part to cooling on the bank and also, perhaps, to westward extension of water from the Danish coast, and the warmer water brought round by, it appears from Chart 3, the SW. Dogger Bank swirl. As to grounds in the Southern Bight, the warmer water which, under normal conditions, would enter through Dover Straits, was, as we have already demonstrated, prevented from doing so for considerable periods of time at this season by the unfavourable winds. Its influence was therefore limited to a small region in the very South of the Bight. We may con-

sequently say that the temperature conditions which characterise all three grounds were neither especially high nor low.

A further point arises from a scrutiny of the charts of the catch anomalies, namely, that on the Danish coast the figures are low and in February and March are mostly associated with negative signs, indicating that the catch per 100 hours fishing was below the mean value. Were it not for the fact that the intensity of fishing in this locality was at that time rather light, the low catches off the Danish coast considered in conjunction with the remarkably high ones in the Silver Pits, Clay Deep, etc., would surely indicate a migration of the fish away from the cold shallows of the coast to the deeper waters offshore. To the small number of hours of fishing is probably attributable, for example, the high anomaly in rectangle M10 in March. The anomaly is 8 cwts. and the number of hours fishing 112. It may be remarked in passing that the catches in all rectangles in which the number of hours fishing was less than 100 have been disregarded. Nevertheless, there is a certain consistency in the low values off the Danish coast which makes it probable that such an offshore migration actually took place and was partly responsible for the greatly increased size of the catches on the deeper water grounds. Such a movement of the fish is, too, in keeping with the commonly held opinion that under stress of circumstances, as extreme cold or heat, fish seek deeper water.

This argument depends to some extent upon the truth of the assumption that an increase in the stock of soles such as evidently began to be felt in 1928 and was still more to be remarked in this, the following year, would affect equally all regions where soles are normally to be found. As this assumption cannot be judged at the moment, it would be safer to conclude that the outstandingly large catches on the deep water grounds were attributable in part to the offshore migration and in part to the general increase in the stock of soles, due perhaps to some particularly abundant year-class.

It will, too, be of great interest to discover, if possible, to what extent the stock has been depleted by the mortality described and whether the catches in 1930 will be lower in consequence. But these, besides being somewhat beyond the scope of the present paper, are questions for which it would be premature to attempt solutions.

In conclusion we should like to thank all those who have been good enough to contribute information, or other assistance, individual acknowledgements of which it would be impossible to make here. We would add that we should be grateful for any further information bearing on the phenomena which have been discussed.

Résumé.

Eine ausserordentliche Erscheinung, die unter anderen am Anfang dieses Jahres von den Fischern festgestellt wurde, war die Menge der toten und verwesten Fische, hauptsächlich Seezungen, die im März und April im Schleppnetz gefangen wurden. Der Fang dieser toten Fische beschränkte sich offenbar auf ein Gebiet, das sich von der Helgoländer Bucht zur East-Anglia Küste erstreckt, aber der Hauptplatz des Sterbens scheint in der Nähe des Terschelling Grundes gelegen zu haben. Dieses Phänomen kann nicht bestimmten Gründen zugeschrieben werden; aber die Temperatur des Wassers fiel längs der kontinentalen Küste so aussergewöhnlich tief (unter —1° C.), dass es nicht unwahrscheinlich ist, dass die Fische durch die Kälte getötet worden sind. Auch die Verteilung der Seezungen wurde insofern beeinflusst, als die Fänge im tieferen Wasser aussergewöhnlich gross waren, sowohl im Verhältnis zu den normalen Fängen wie zu den Fängen im seichteren Wasser vor der dänischen Küste. Diese Zunahme wird teils einer Abwanderung von der Küste als Folge der niedrigen Temperatur des Küstenwassers und teils einer allgemeinen Vermehrung dieser Fischart zugeschrieben. Weitere Auskunft über diese Frage ist erwünscht.

Some Observations concerning the Stock of Haddock in the Skagerak and Kattegat.

By

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During the later years from 1925, the Swedish Hydrographic-Biological Commission has had particulars collected of the quantity of haddock of different marketable sizes landed in the fish harbour of Gothenburg. As the greatest part of the Swedish caught haddock is nowadays landed in this harbour, one obtains from these particulars a rather good idea of the nature and the variations of the stock of haddock in Skagerrak and Kattegat, where the Swedish fishermen make their catches.

The quantity of haddock landed in Gothenburg during the time 1920—1928 will appear from the table below.

Year	Haddock sold (kg.)
1920	4,297,425
1921	3,895,950
1922	4,021,500
1923	3,056,250
1924	2,559,375
1925	3,816,600
1926	3,744,150
1927	4,678,050
1928	7,454,025

The table shows that the landings vary very greatly. From 1920 to 1924 they gradually decrease. After the latter year they increase and attain in 1927 and especially in 1928 very high figures.

The total quantity of the landings, however, changes very much during the different months of a year. Probably this variation is chiefly

due to the fact that the haddock fishery during some months is more or less neglected for other fisheries, especially the herring and mackerel fisheries. During the first two or three months of the year the landings of haddock are comparatively small. This is the time for the winter herring fishery. Weather and ice conditions may also be the cause of

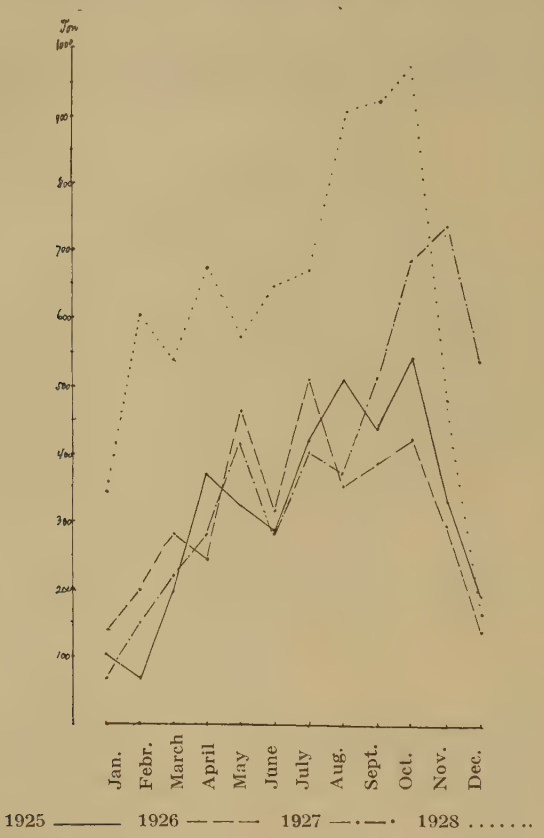

Fig. 1. The Landings of haddock (kg.) in the fish harbour of Gothenburg during the time 1925—1928.

the small landings during this season. During the following month, in spring, the landings increase in quantity but decrease again during the mackerel fishery (May—June). This is generally the case during August and September also, when the drift-net fishery for herring is going on, as well as during the last month of the year, when the winter herring fishery has commenced. It is remarkable, however, that the landings of haddock in Gothenburg were larger than usual during December 1927 and during the beginning of 1928.

On the Swedish fish market four size classes of haddock are recognised (see fig. 2); I "large" 40- -60 cm., average 45—48 cm.; II "medium" 33—45 cm., average 37 cm.; III "small" 28- -38 cm., average 32 cm.; IV "extra small" 22—32 cm., average 27 cm. As appears from fig. 2 the bulk of haddock landed in Gothenburg consists of "small" and "extra small". Still smaller haddock is, however, landed by the trawlers, but is sold directly to the fish-meal factories and is not included in the specifications from the fish harbour. The percentage of the diffe-

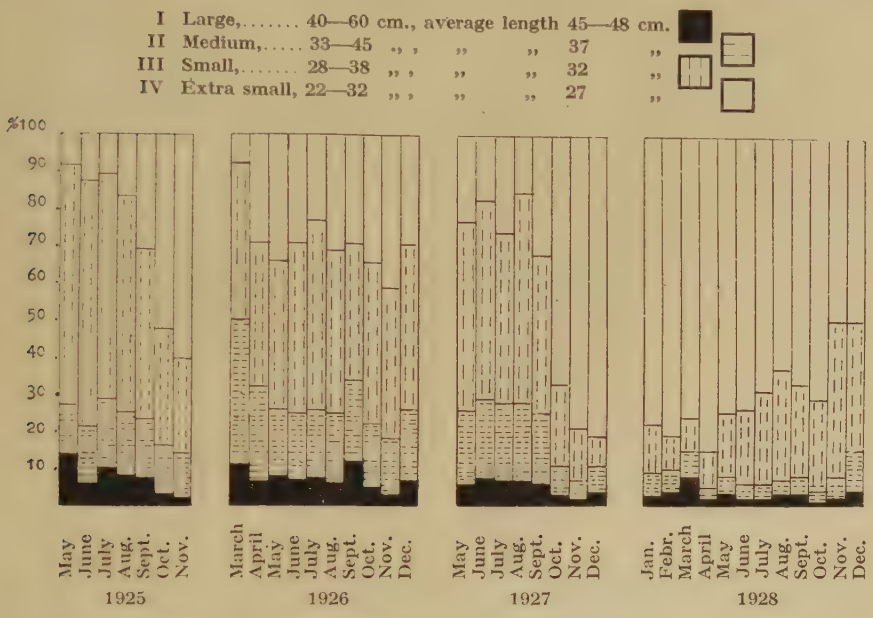

Fig. 2. Landings of different size haddock in the fish harbour of Gothenburg (1925—1928). (Quantity per month in per cent. of the total landing).

rent size classes in the landings during different seasons is not quite the same during each of the years 1925, 1926 and 1927. During 1925, as well as during 1927, "medium" and "small" predominate in the catches during spring and summer, but "extra small" during the autumn. During 1926, on the other hand, "extra small" do not play such a prominent part, and "medium" and "small" also predominate now in the catches during the autumn. During 1928 the "extra small" predominate to a large extent; in the autumn of this year, however, the "small" haddock (III) are more numerous than in autumn 1927. This is probably due to a rich older year class (see below). When such a rich year class does not exist the "extra small" are abundant, as a rule, in the

catches during the autumn. This is especially noticeable during 1927, when the 0-group was very strong (fig. 4). At the same time the fishery is shifted from the deep fishing places North and West of Hanstholm and Hirshals towards more shallow areas in the eastern Skagerak and Kattegat. This refers especially to the fishery with Danish seines, which gives the largest total catches of haddock. The great increase of landings of "extra small" haddock during the autumn of 1927 synchronized with a considerable increase of the total landings of haddock in Gothenburg.

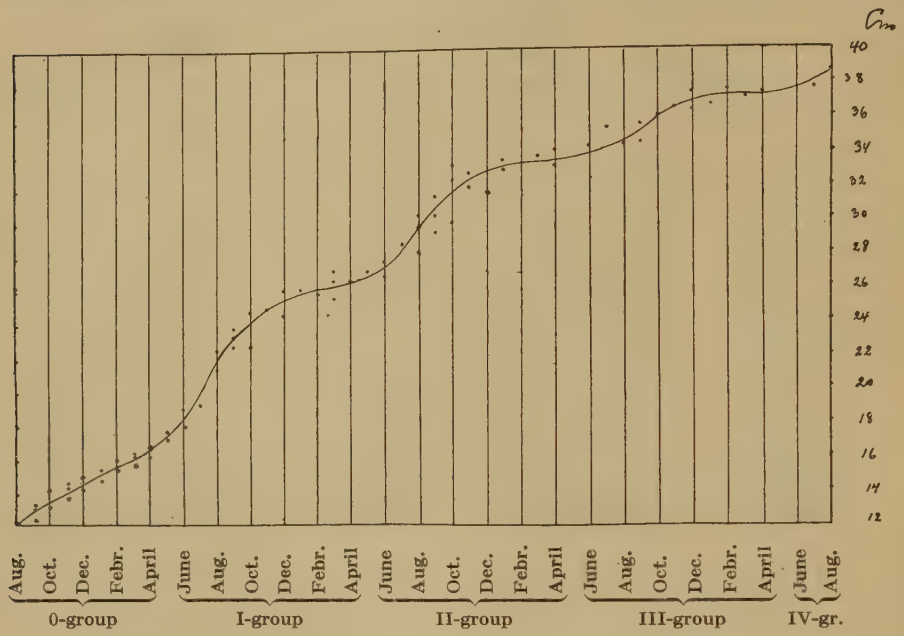

Fig. 3. The growth of the haddock in Skagerak and Kattegat.

In order to enable a comparison of the size of the haddock during different years and months and of the size classes on which the commercial sorting is based, I have drawn a diagram (fig. 3) showing the average size of the haddock at different ages and at different months of the year. The dots indicate the average values of each sample. The diagram shows that haddock corresponding in size with "extra small" are chiefly individuals belonging to the I-group and, to a smaller extent, to the II-group. The I-group attains during the autumn a size sufficiently large to be caught by trawlers and Danish seines. This is the reason why an increase of the "extra small" haddock in the catches in many cases sets in during the autumn. The age of the haddock in the other com-

mercial size classes will, without difficulty, appear from a glance at the diagram (fig. 3).

An age-determination made on scale and otolith samples of haddock during the years 1924—1928 gave the following result (fig. 4).

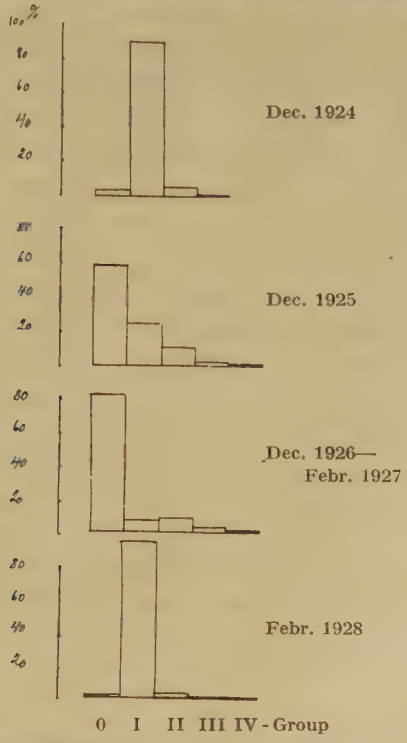

Fig. 4. Age determination of haddock caught in Skagerak during 1926—1928.

In December 1924 the stock of haddock belonging to the 0-group was very poor, whereas the I-group was remarkably strong and quite predominated in the catches. This is, consequently, the year class of 1923 which, according to THOMPSON[1]), was also very rich in the North Sea. The year class seems, however, to have been represented in comparatively small quantities in the later samples from Skagerak which I have had the opportunity to examine. During December 1925 it amounted to only little more than 10 per cent. of all year classes taken together. But the increase of the landings during 1925 in comparison with those during 1923 and 1924, as well as the relatively large quantities of "small" and "medium" haddock during 1926 — even during the autumn — may be due to this year class. During December 1925, as well as during December 1926

[1]) H. THOMPSON, The Haddock of the North-Western North Sea, Rapp. & Proc. Verb. Vol. LII, p. 70.

and February 1927, the 0-groups, *i.e.* the year classes of 1925 and 1926 respectively, predominate. The year class of 1925 seems, however, to have been rather weak, as during 1926 it already plays — as I-group — an inconsiderable part in the landings. The year class of 1926, on the other hand, turned out quite differently. As 0-group it was very strong and quite predominated in the catches during the winter 1926—1927. During February 1928, when it forms part of the examined samples as I-group, it amounts to 93 per cent. of the catches. In the autumn 1928 it predominates as II-group, in one sample forming as much as 62 per cent. of the whole. A rather well developed 0-group from 1928 seems also to exist.

On the Collection and Preparation of Fish Scales.

By

Michael Graham,

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In the case of fish, such as the herring, whose scales are covered by thin and colourless dermal tissue the simplest and best method of mounting is that adopted by LEA and others, in which the scales are wiped in the fingers immediately after removal from the fish and straightway mounted on a droplet of albumen on a glass slide. But this simple procedure is only possible when samples are brought to a laboratory or similar place ashore or aboard a research ship, where there are facilities for handling glass slides. It is almost impossible, for example, in collections made on commercial fishing boats. Furthermore, the scales of some fish, being more opaque than herring scales, are best mounted in glycerin jelly. (BRANDT's formula is suitable and gives preparations which have been stored for six years without appreciable change.)

Where the scales cannot be mounted immediately it has been common practice to place them in small envelopes, which are allowed to dry. In LYMAN DUFF's collection of cod scales, which was made at shore stations, the envelopes were laid out separately from each other and dried slowly, taking one or two days. The scales were found to lie flat on a slide and were examined dry. DUFF makes no mention of cleaning being necessary; but it is our experience that the adherent pigmented dermal tissues must then be removed or bleached.

Leaving aside for the moment the case of the scale with pigmented dermal tissues, we may consider the technique of collecting and preparing the scale with delicate and colourless dermal tissues, under such conditions that the scales may not be mounted immediately on collection. In this case we have followed a suggestion of Mr. EINAR LEA, designed to eliminate the lengthy cleaning of dried scales, that the scales should be preserved between sheets of absorbent paper made damp with dilute formaldehyde. Small books have been made of blotting paper, about 3 inches by $1^1/_4$ inches in size. The blotting paper is interleaved with

a much smaller page of thin cartridge paper, on which the length and sex of the fish is recorded. The covers of the booklets are made of thin cartridge paper on which may be entered the particulars of the haul etc. The books with the scales within them are placed in metal boxes in which there is a pad of cotton soaked in 2 per cent. formaldehyde at the bottom of the box, and another pad damp with formaldehyde in the top. Scales thus preserved are clean of excess of slime, which apparently soaks into the blotting paper, and when they are not cumbered with pigmented dermal tissue, they may be mounted in glycerin jelly without any cleaning whatsoever.

In the case of scales with pigmented dermal tissue it was formerly the practice to soak the dry scales in dilute alkali and then remove the adherent dermis and epidermis with needles, or by rubbing between the forefinger and thumb. A considerable saving of time was made by bleaching the tissue instead of removing it mechanically, using sodium peroxide, as has already been described (Graham, p. 9). Unfortunately this bleaching method had also the disadvantage that unless the sodium peroxide were thoroughly removed bubbles tended to appear in the preparations, and for complete removal of the peroxide it was necessary to use ten changes of water. This lengthy washing has now been superseded by the use of sodium sulphite solution. The scales are left overnight in the peroxide solution (17 hrs.), and in the morning the peroxide solution is drawn off and solution of sodium sulphite immediately added. The scales are then mounted directly from the sulphite solution into glycerin jelly. The preparations so produced are perfectly clean and clear of bubbles. In this way two assistants, working without haste, mount 6 or 8 scales from each of 100 fish in about 4 hours — 1 hour placing the scales in freshly made peroxide solution, and 3 hours carrying out the remainder of the operations on the following morning. The strength of solutions to be used depends on what method has been adopted for preservation of the scales. Where these were preserved in spirit we use 2 per cent. peroxide and 2 per cent. sulphite solutions; where the scales have been dried in envelopes we use $^1/_2$ per cent. strength for both solutions, since in this latter case the stronger solutions cause slight maceration at the margin of the scale.

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Michael Graham. Studies of Age-Determination in Fish. Part I. Fishery Investigations. Series II. Vol. XI. No. 2. London 1929.

G. Lyman Duff. Factors involved in the Production of Annual Zones in the Scales of the Cod (*Gadus callarias* Linnaeus). Cont. Canadian Biol. N. S. IV. No. 21. Toronto 1929.

Reviews.

G. H. Fowler and E. J. Allen. Science of the Sea; an elementary Handbook of Practical Oceanography, etc., prepared by the Challenger Society. Second Edition edited by E. J. Allen, D. Sc., F. R. S., Clarendon Press, Oxford 1928.

The first edition of this useful book, intended to be a practical guide for all those who are willing to avail themselves of the opportunity to contribute to our knowledge of the ocean and the myriads of organisms of all description, roaming and rambling about in the vast expanse of the blue waters, appeared in 1912 and was edited by G. H. Fowler.

To cope with the aim of the Editor and to afford in concise and yet intelligible form an introduction to the study of oceanography in its widest sense must be indeed no small task. This book is primarily intended to be a handbook for practical laymen, desirous to do some work preferably in out-of-the-way places but also even in our home waters, for the sake of Science, and so it must convey not only elementary information but next to that, practical hints on what to do and how to manage. And it is highly to be appreciated that apparently the interest taken in such work has necessitated in the course of time a new edition, in which progress in knowledge or working methods could be given due regard.

A host of well known names is attached to the thirteen chapters in which this book is divided. Some chapters are more devoted to instructing interested collectors about the material to be met with, other ones contain useful hints about collecting itself and how to treat the spoils of the sea.

To the present writer it seems that the opening chapters on "The Air" and "The Water" have benefited most by re-editing, though those on "Tropical Shore Collecting" and "Floating Plants" likewise show a remarkable increase and enlargement. Other chapters have been revised and brought up to date. We may mention two valuable enrichments, compared with the first edition: one the article on coral reefs and islands by J. Stanley Gardiner, in which the theory of Daly is expounded and the other on "Phytoplankton and Borderland Forms" written by that great authority on the subject, Marie V. Lebour.

The greatest credit is due to those articles which convey practical advice on "Equipments", "Dredging, Trawling and other methods of Fishing" and "Preservation of Marine Organisms". Here the wholly experienced sailor and investigator comes to the fore. Handling the nets,

shooting and hauling cannot well be dealt with in a book; such methods must of necessity be mastered by practice; but to know a net and how it should be treated, is essential. From the scope of the book it is only natural that not too much space is devoted to commercial fishing; operations with a definite scientific purpose are more largely dealt with, and some knowledge of these must be acquired before embarking on marine expeditions, however small they may be.

The illustrations in the handbook are nearly all the same as in the first edition; they are suitable for giving a general idea of the wealth of forms the collector may expect, and are useful in providing the barest outlines of classification of material. In a work like this, where so much depends on illustrations to which the general reader will readily turn, figures are of great importance. By far the greater part of these are copied from other works, notably from "Challenger" publications; the source, however, is rarely indicated.

Perusing the pages of the book it is somewhat surprising to learn how little we know of such a striking and puzzling phenomenon as the assemblages of Sargassum in the North Atlantic Ocean, of which particular floating species the systematic place and the mode of sexual reproduction, if any, is still unknown.

Another case in point is the phantom of the seas, the "marvel of all marvels", the famous "sea serpent". Tackling the subject with throbbing pulses we are soon disappointed to find that Prof. D'ARCY W. THOMPSON has found nothing conclusive to reveal at last the greatest mystery of the waters; in fact his present report is absolutely the same as that of sixteen years ago though, of course, this is not the author's fault. A good series of mysterious apparitions of "sea serpents" has since been recorded, but fishermen's yarns or inconclusive reports of naval officers and others are, if ever published, difficult to get and liable to be altogether overlooked. Whether a giant seal, a Plesiosaur or a Chimaera of imagination, the "sea serpent" still haunts the waters of our globe as the most mysterious being, the most thrilling big game that ever remained for the romantically minded to conquer. — In the preceding pages the last named author deals with whales and, in speaking of the Greenland whales, mentions *inter alia* that (p. 430): ".....the great Dutch settlement of Smeerenberg, in Spitzbergen, employed at one time (about the year 1680) 260 ships and over 14,000 men". This settlement of Smeerenburg (not Smeerenberg), situated on Amsterdam Island off the North-west coast of Spitzbergen, was, however, in full swing only soon after the very outset of the whaling industry and was already abandoned by about the year 1634. Statistics of that time are not available, but we know that in 1680, the particular year named by the author, the number of Dutch vessels engaged in this business was 148, landing 1373 whales, according to ZORGDRAGER'S well-known book.

It is a matter of some surprise that nowhere in the book is mentioned WEGENER'S hypothesis about the origin of oceans and continents. The chapter on "the Sea Floor" by the late Sir JOHN MURRAY has been reprinted in it's entirety from the first edition and though the present book is in the first place a guide and not a scientific treatise it might have been

well-advised to explain a theory which bids far to inspire lively interest in all those who ask for an explanation of the origin of oceans and the marvels of palaeogeography.

The last chapter, on Logs, Notes and Labels, etc. has been likewise reprinted as it was originally written by G. H. Fowler. The author has included some "conversions" which are indeed useful, but are drawn up with absolute disregard, if I may say so, to continental-European readers. We, on the continent, are continually facing such awkward problems as the exact dimension of an inch, of a foot; we are asking ourselves such questions as: "what exactly is a "stone", a "lb", what is a "pint", a "gallon"?" None of this is indicated at all, but explanations of such daily puzzles could be easily given. J. J. T.

H. H. Poole and W. R. G. Atkins. Photo-electric Measurements of Submarine Illumination throughout the Year. Journ. Marine Biol. Assoc. XVI, No. 1, Plymouth 1929, pp. 297—324.

A review of previous researches of the same kind has been given in the "Journal du Conseil" Vol. IV, No. 1, March 1929, p. 108. The apparatus used for the measurements has been improved mainly by introducing an opalized glass window. By this device the uncertain and troublesome corrections for obliquity of illumination were rendered almost negligible. The whole apparatus has been made more handy and better insulation has been secured.

Numerous measurements are given in table I for the calendar year 1928. Most of them have been taken at the international hydrographic station E_1 situated about 10 miles SW. of the Eddystone lighthouse and about 20 miles from the Plymouth Sound breakwater; they have been distributed throughout the year, although the summer months are most strongly represented. In table II collected results from station E_1 are given from the year 1925 up to January 1929 in order to show possible seasonal changes in the opacity of the water. It is stated that the high opacity of the surface layers which occurred in the autumn of 1927 and declined with the approach of winter was not repeated in 1928 and it is expressly mentioned that no single factor appears to be mainly responsible for the variation in the values of the absorption coefficient throughout the year and throughout the day. As possible causes are mentioned the inorganic matter in suspension, the plankton, and the organic "débris" resulting from living organisms or derived from the land or the sea bottom. At the time when the main spring diatom outburst in 1928 took place the water at E_1 was exceptionally clear and it thus seems that our former ideas with regard to the changes in the opacity of the sea-water certainly demand the control which is now given by the extensive work under review. The changes from time to time and from place to place are by no means small. On a certain occasion it has even been found that the coefficient of absorption had the value 0.08 in the surface-layers while at a depth of 25 meters it was almost 3 times as great. The authors intend to make further studies on this highly interesting problem and have especially in view the correlation between the opacity of the water and the accumulation of the zooplankton. Martin Knudsen.

R. Kolkwitz. Das Thermoplanktometer. Bericht der Deutschen Botanischen Gesellschaft, Bd. XLVII, 1929, Heft I. Berlin 1929.

Thermoplanktometer is the name given by the author to an apparatus for determining the density of sea-water which was designed by him in co-operation with Dr. Vilhelm Irgens Pettersson. The name is commended by the author as being euphonic, distinctive, descriptive of the principle on which the apparatus is based and reminiscent of the purposes for which it may be employed.

Densities are determined by observing the temperature at which a sinker floats in equilibrium totally immersed in the sample of sea-water, a method which has been employed by several previous workers[1]).

The apparatus is very compact and consists of a cylindrical tinned-copper vessel about 7.5 cm in diameter and 10.5 cm high fitted with a rectangular glass window about 2.5 cm in width and 8 cm high. The lid of the vessel has three openings through one of which projects the handle of a wire stirrer, a thermometer is held in the second and the third and largest permits the introduction and removal of the sinker and is closed when the apparatus is in use. A vertical copper spiral is fixed below the lid, concentric with the largest hole and extending almost to the base of the vessel. The sinker, of weight about 20 g, remains within this spiral and is visible through the window in the containing vessel. The thermometer has a very long bulb extending from just below the lid nearly to the bottom of the vessel. The whole of the scale of the thermometer is above the level of the lid and has a range from 12° C to 24° C subdivided into intervals of 0.02° C.

The temperature of the sample is raised or lowered as may be necessary, until the sinker floats in equilibrium with the surrounding liquid.

A change in equilibrium temperature of 1° C corresponds to about 0.00025 g/ml change in density and it is stated that equilibrium temperatures can be determined to within 0.01° C.

The paper does not give precise details of the procedure to be followed in raising and lowering the temperature and in determining the equilibrium temperature nor any results of determinations made with the apparatus, whereby its performance under conditions of use might be judged.

The paper is, however, only a preliminary announcement and a further more detailed paper is promised. Verney Stott.

B. Schulz. Bericht über die Fortschritte der Ozeanographie (1925—28). Geographisches Jahrbuch. Band XLII, pp. 327—365. Gotha, 1929.

The new number of this extremely useful periodical report is a very impressive publication indeed, since, from a mere glance at its 700 or so references, one immediately realises with what rapidity the literature list

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[1]) "Journ. Wash. Acad. Sci.", 1917, VII 605, "Journ. Chem. Soc.", 1926, *129*, 1263 and "Journ. du Conseil International pour l'Exploration de la Mer", 1928, III, 328.

of the science is growing. In the preceding number (noticed on page 356 of the first volume of the Journal du Conseil) Professor SCHULZ had a period of ten years to deal with. The present report is built up under the same heads as its predecessor; these heads can be seen on referring to the earlier notice just mentioned. Under each literature classification, we are given not only an exceedingly full list of papers published, but a most welcome digest of the main ones. The losses by death, which Oceanography has sustained in the period under review, are:— VICTOR HENSEN, Sir WILLIAM A. HERDMAN, ALFRED MERZ, R. STERNECK, and FINN MALMGREN. In the case of ALFRED MERZ, it is possible to refer to no less than ten obituary notices.

In remarking that quite a series of new periodical publications dealing with marine research matters has appeared, Professor SCHULZ hails the Journal du Conseil as of first importance, and speaks of the important place which it has already gained as a publication medium for researches carried out in the North-west European shelf seas, and the adjoining portions of the North Atlantic. J. N. C.

B. NIKITINE. Les Migrations Verticales Saisonnières des Organismes Planktoniques dans la Mer Noire. Bulletin de l'Institut Océanographique, No. 540. Monaco 1929. pp. 1—24.

In this publication Professor NIKITIN gives some results of observations on the seasonal changes in the vertical distribution of certain plankton animals in the Black Sea. The information is derived from collections at 260 stations taken during the years 1923 to 1927 with the vertical Nansen net, a surface net, and a horizontal closing net.

He divides the zooplankton living in the layers from the surface down to 75 metres into two groups; the "formes constantes", occurring all the year round, and the "formes variables" present only during certain seasons. The percentage of the "formes constantes" increases with depth, until from below 75 m. down to the "limite inférieure" the "formes constantes" only are found.

The paper deals only with those forms which show a seasonal vertical migration and these are taken in two groups. 1) The "chimopelagiques" forms which are present throughout the year, being in winter and spring in the upper water layers and in summer and autumn descending to deeper levels. These are *Calanus finmarchicus*, *Pseudocalanus elongatus*, *Oithona similis*, *Sagitta euxina*, and *Pleurobrachia pileus*. 2) Those forms present only during the warm season, e.g. *Centropages Kröyeri*, *Evadne Nordmanni*, *Evadne spinifera*, and *Podon polyphemoides*.

Professor NIKITIN gives diagrams showing how the upper limit of distribution for each species in the former group more or less coincides with the seasonal changes of the various isotherms. *Calanus finmarchicus* and *Pseudocalanus elongatus* for instance are scarce in water layers above the isotherm of 13° C., *Oithona similis* appears to keep below the 14° isotherm, *Sagitta euxina* 10°—11°, and *Pleurobrachia pileus* 12°. The second group, however, being warm season forms occur in the upper water layers during the summer and autumn keeping always above certain isotherms;

the lower limit for *Centropages Kröyeri* and *Evadne Nordmanni* being 12° C., *Evadne spinifera* 15°—16°, and *Podon polyphemoides* 13° C.

The author gives in this paper no data whatever from which the reader may satisfy himself as to the validity of the conclusions; in a previous publication[1]), however, tables are given showing the data collectively for the years 1923 to 1925. It is regrettable that in these tables actual numbers are not given, the quantities being indicated merely by symbols. These tables seem to show that in his main conclusions the author is correct, although his diagrams must be regarded purely as such and not as the delineation of actual results.

After a brief discussion the author believes that he can conclude that the annual variations in temperature can be considered as the principle factor in the seasonal vertical migrations of the plankton in the Black Sea, but the migrations of phototropic forms such as *C. finmarchicus* and *S. euxina* are due not only to temperature variations, but also to variations in light intensity; that the eurythermal forms only react feebly to changes of temperature and have no seasonal vertical migrations.

In explaining the difference between his own conclusions and those of the reviewer based on work at Plymouth Professor Nikitin rightly points out that the annual differences in temperature may be as much as 18° to 19° in the Black Sea as against 6° to 7° at Plymouth, and that temperatures of 24° C. may be reached which is perhaps well in the region of the critical temperatures for the phototropic behaviour of the animals in question. F. S. Russell.

Birgithe Ruud Føyn. Investigations of the Phytoplankton at Lofoten, March—April, 1922—1929. Norske Videnskaps-Akademi i Oslo. I Mat.-Naturv. Klasse 1928, No. 10. Oslo 1929.

The unicellular plankton is the subject of this work, embracing collections made by various ships when on fishery investigation cruises round the Lofoten Islands over a period of seven years. The samples were taken chiefly in March and April, the spring production being at its height in April and only lasting about one month. The importance of this research lies in its connexion with the food of young fishes, especially of the cod which spawns at Lofoten in the early spring and feeds on the small planktonic animals which themselves feed on diatoms and other unicellular organisms. Mr. Oscar Sund has already carried on researches in these regions each spring from 1922 to 1927 for the Norwegian Fishery Board, in order to throw light on the relation between the prevalence of the newly hatched young cod and the hydrographical-biological conditions.

The question as to where the diatoms, which form by far the largest part of the phytoplankton, obtain their nourishment is here involved, for the Baltic Current, laden with plant food in the form of salts, loses much of this nutritive matter when it arrives at Lofoten, and it has to

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[1]) B. Nikitin. La distribution verticale du plancton dans la Mer Noire. I. *Copepoda* et *Cladocera*. Travaux du Laboratoire zoologique et de la Station biologique de Sébastopol. Academ. des Sciences de l'Union des Républ. Sociét. Social. Series II. No. 9. 1926. pp. 93—140. (In Russian with a French Summary.)

be determined whether the large spring growth is due to the supply of salts from the shore or the nutritive material circulated from the deep sea by vertical currents. The author concludes that the food salts come mainly from the shore. The time for the spring production of diatoms depends upon the temperature and begins each year directly after the snow has begun to melt, the quantity depending on the supply of fresh water.

The water samples were collected with the Ekman-Nansen water-bottle and the temperature taken by a Richter reversing thermometer. Samples were taken from the water-bottle for the determination of salinity, pH, oxygen and for examination of the plankton. The plankton was mostly fixed by GRAN's method in FLEMMING's fluid, a few samples in formalin and in sublimate. Only the first was satisfactory. The preserved plankton was investigated quantitatively by LOHMANN's centrifuge method. Although many species were present the predominance of a few was marked, and attention was specially concentrated on the diatoms *Fragilaria oceanica*, *Skeletonema costatum* and *Thalassiosira gravida*. With the exception of *Phaeocystis pouchetii*, which is a flagellate, the diatoms were the only organisms of any practical importance and these were almost entirely arctic or boreal forms. Several dinoflagellates occurred but not in large numbers. Skeletonema and Fragilaria attained their maxima first; later on the species of Chaetoceros and also Phaeocystis. The growth begins at the head of the Vestfjord close to the shore and spreads out gradually until the mouth is reached where it remains longest. The numbers were greatest where the temperature and salinity were lowest and indicated most mixture with fresh-water, and where the fresh-water has its maximum content of nutritive salts.

The investigations were most complete in 1923 and 1926 and the average increase of oxygen content per day in 1923 was the greater, which probably indicates a larger plankton production, corresponding with the fact that the flow of water from the Sneiselven opening into the Vestfjord was greater in 1923 than in 1926.

Samples from the Edge of the Shelf were very rich in diatoms from the middle of April — much richer than any station in the Vestfjord — but the author is of the opinion that this has no connexion with the Vestfjord flowering. Different species were found there and the large number is thought to be due to the drifting of neritic forms which find their nourishment in the salts brought up to the surface by the vertical currents.

M. V. L.

H. H. GRAN. Investigation of the Production of Plankton outside the Romsdalsfjord 1926—27. Conseil Perm. Int. pour l'Explor. de la Mer. Rapp. et Proc.-Verb. Vol. LVI. Copenhague 1929.

GRAN fügt ein neues besonders wertvolles Glied an die Reihe von Untersuchungen an, welche seit mehr als 30 Jahren von ihm selbst und anderen über das norwegische Plankton sowohl vor der Küste von Romsdalen wie auch weiter nördlich und südlich ausgeführt worden sind. Ein Schnitt senkrecht zur Küste, welcher bis über den Absturz der Küstenbank zur

Tiefsee hinaus und bis in echtes Golfstromwasser hineinführt, wurde 1926 und 1927 eine Reihe von Frühlings- und Sommermonaten hindurch qualitativ und quantitativ in Bezug auf das Zentrifugenplankton bearbeitet. Der Schnitt ist etwa 50 Seemeilen lang. Auf ihm liegen 6 Stationen. Die untersuchte Wassermenge betrug gewöhnlich 50 ccm, oft aber auch weniger, nicht selten nur 5 ccm. Die regelmässig untersuchten Tiefen waren: 1 m, 10 m, 25 m, 40 m, 75 m. Die Ergebnisse werden unter eingehender Berücksichtigung der Literatur und auf Grund einer ausserordentlich grossen persönlichen Erfahrung besonders nach der kausalen Seite hin verarbeitet.

"We may consider it as proved that the limiting factor in the production of plankton in the majority of cases is the available amount of nutritive salts in solution". Dieser die Arbeit einleitende Gedanke steht im Mittelpunkt der ganzen Betrachtung. Doch wird die Mitwirkung anderer Faktoren stets in Betracht gezogen.

Im Untersuchungsgebiet ist das Plankton Anfang März noch sehr arm. Ende März jedoch hat es schon das Frühlingsmaximum der Diatomeen erreicht, das aber Ende April bereits wieder erloschen ist. Die Diatomeen sind fast verschwunden. Die Frühlingswucherung beginnt an 2 getrennten Stellen, unmittelbar an der Küste (Julsund) und draussen am Schelfrand (Storeggen), doch verschmelzen die beiden Wucherungsgebiete bald. Während der Beginn der Wucherung hauptsächlich durch *Skeletonema costatum* gekennzeichnet war, herrschte später hauptsächlich *Chaetoceras debile* vor, bei der äusseren Station jedoch im 2ten Jahre *Asterionella japonica*. Später im Sommer beherrschen die im März noch minimal entwickelten Ceratien das Gebiet.

Gran sucht diese Verhältnisse und zugleich die ähnlichen von Frau Ruud-Föyn bei den Lofoten gefundenen zu verstehen teils aus der Nährstoffzufuhr, teils aus der Zufuhr eines Ausgangsmaterials der betreffenden Arten, teils aus den spezifischen Lebensbedürfnissen der Arten. Dem doppelten Ausgang der Frühlingswucherung entsprechen 2 verschiedene Nährstoffquellen, einerseits an der Küste die starke Zufuhr von Landwasser zur Zeit der Schneeschmelze, andererseits am Schelfrand das Aufsteigen von Tiefenwasser. Letzteres dürfte eine Folge davon sein, dass am Kontinentalabfall unter dem Einfluss der Erdrotation die Küstenströmung emporgedrängt wird. Dass dies Empordrängen bald wieder aufhört, wird aus dem Umstande verständlich, dass schon Ende März eine 10 m dicke leichtere Wasserschicht das Tiefenwasser überlagert. Als Ursprungsgebiet der vorherrschenden Diatomeenarten kommt die nördliche Nordsee und die Gegend der Shetlandinseln in Betracht. Unter Berücksichtigung der Stromgeschwindigkeiten längs der Küste ist anzunehmen, dass die Keime der Asterionellabevölkerung vor Romsdal sich Mitte März bei den Shetlandinseln befanden, die der Skeletonemabevölkerung nahe den Lofoten jedoch schon Mitte Februar jenes Ursprungsgebiet verlassen hatten. Was das Verhalten der verschiedenen Arten betrifft, die in einem besonderen Abschnitt einzeln besprochen werden, so ist besonders bemerkenswert, dass die langsam wachsenden, wenig nahrungsbedürftigen Ceratien im Sommer vorherrschen, wo die Nahrungszufuhr den Diatomeen nicht mehr genügt. Sie sind vielleicht auch durch ihre aktive Beweglichkeit befähigt, tiefere Wasserschichten mit auszunutzen.

Durch Vergleich der Periodizität des Planktons vor Romsdal mit den Ergebnissen in anderen Gebieten kommt Gran zur Aufstellung von 3 Typen jahreszeitlicher Planktonentwicklung.

1) Diatomeen sind vom Frühling bis zum Herbst reichlich vorhanden. Die Nährstoffzufuhr ist gleichmässig, entweder vom Lande her oder durch Verticalcirkulation aus der Tiefe. Ein Beispiel ist der Limfjord.
2) Maxima und Minima des Planktons wechseln dauernd. Die Nährstoffzufuhr ist wechselnd, z.B. stärker zur Zeit der Schneeschmelze und in regenreichen Perioden. Verticalcirculation findet im Sommer nur vorübergehend statt. Beispiel: Loch Strivan in Schottland.
3) Das Plankton hat nur ein einziges grosses Frühlingsmaximum zur Zeit der tiefsten Temperatur des Oberflächenwassers, eine Folge der Schneeschmelze. Später folgt ein ärmeres Ceratienplankton. Die Wassercirculation spielt im Sommer keine Rolle. Beispiel: Norwegische Küstengewässer.

Übergänge zwischen diesen 3 Typen kommen vor. E. H.

H. H. Gran. Quantitative Plankton Investigations carried out during the Expedition with the "Michael Sars", July—September 1924. Conseil Perm. Int. pour l'Explor. de la Mer. Rapp. et Proc.-Verb. Vol. LVI. Copenhague 1929.

Auch diese Arbeit gründet sich wie die vorige auf Untersuchungen mittels der Zentrifuge. In der Einleitung und gelegentlich später wird die viel umstrittene Methodik besprochen unter Bezugnahme auf die Ansichten Uttermöhl's, Allen's, Lohmann's und Wulff's. Bekanntlich pflegt Gran das Material in konserviertem Zustande und zwar nicht auf alle Bestandteile, sondern nur auf die vorherrschenden Arten quantitativ zu untersuchen. Er gibt hier gelegentlich (p. 6) beachtenswerte Mitteilungen über einige Kunstgriffe zur Verringerung der Fehler.

Wenn der Verfasser sagt, dass man, um den Zusammenhang zwischen der Verteilung des Planktons und den äusseren Lebensbedingungen zu finden, entweder die qualitativen und quantitativen Unterschiede innerhalb eines grösseren Gebietes oder die Veränderungen an ein und derselben Stelle im Wechsel der Jahreszeiten untersuchen müsse, so wird man ihm zustimmen. Der Berichterstatter kann sich jedoch nicht davon überzeugen, dass man sich auf die Zählung der vorherrschenden Arten beschränken müsse, und dass es von geringem wissenschaftlichen Werte sei, den Gesamtgehalt einer Wasserprobe an Plankton festzustellen. In vielen Fällen sind ohne Zweifel die Zahlen für das Gesamtplankton oder für grössere Gruppen (etwa die Diatomeen insgesamt) beträchtlich ausdrucksvoller und leichter aus den Lebensbedingungen verständlich als die für einzelne Arten. Dazu kommt, dass für den Vergleich verschiedener Meeresteile und für zusammenfassende Darstellungen grösserer Gebiete im allgemeinen die Werte für einzelne nicht überall vorhandene Arten nicht geeignet sind, wohl aber jene Gruppenwerte. Dass sich gegen deren Genauigkeit manches einwenden lässt, und dass die bezügliche Methodik

noch keineswegs vollkommen ist, soll nicht geleugnet werden. Immerhin dürfte die heute erreichte Genauigkeit für viele Zwecke genügen.

Die Untersuchungen auf der Aus- und Heimreise zwischen Norwegen und der Davis-Strasse zeigen, dass in den warmen atlantischen Wassermassen des Nordmeers die Coccolithophoride *Pontosphaera huxleyi*, der wichtigste Producent organischer Substanz ist, so weit der Salzgehalt des Wassers nicht unter 35 ‰ sinkt. Wo Coccolithophoriden massenhaft vorkommen erscheint das Wasser oft milchig verfärbt. Trotz relativer Armut des Planktons in diesem Gebiet findet sich überall in den obersten Wasserschichten eine Sauerstoffübersättigung. Erst zwischen 25 und 50 m Tiefe überwiegt der Verbrauch die Produktion an Sauerstoff. Unmittelbar bei den Färöern fand sich ein reiches Diatomeenplankton. Seine Tiefenverteilung war ebenso wie die der physikalischen Eigenschaften des Wassers eine sehr gleichmässige, was wohl eine Folge von aufsteigendem nährstoffreichem Tiefenwasser ist. In den übrigen Gebieten herrschten meist kleine Flagellaten vor.

In der Davis-Strasse entsteht längs der Küste von Grönland im Mai ein arktisch-neritisches Diatomeenplankton. Im Sommer findet sich statt dessen eine "Leptocylindrus-Gemeinschaft", hauptsächlich durch Diatomeen von südlicherer Verbreitung, wie *L. danicus* gekennzeichnet, welche durch die Küstenströmung nordwärts getrieben werden dürften. Die Wassertemperatur beträgt hier 3°—5°. Weiter westlich in der Nähe von Cumberland, bei 1°—3° Wassertemperatur, findet sich das mehr ozeanische "Labradorica-Plankton", so genannt nach einem veralteten Namen der Leitform *Ceratium arcticum*. Der relative Reichtum dieses Planktons dürfte auf Nährstoffzufuhr durch das Polareis zurückzuführen sein, von dessen Einwirkung das Vorkommen von Eisdiatomeen im Plankton zeugt.

Ausser der Behandlung der verschiedenen Gebiete unter eingehender Berücksichtigung aller Literatur enthält die Arbeit ebenso wie die vorige eine Besprechgung der einzelnen Arten und das gesamte Zahlenmaterial in Tabellen. E. H.

1) H. Blegvad. Quantitative Investigations of Bottom Invertebrates in the Limfjord 1910—1927 with Special Reference to the Plaice-Food. Report of the Danish Biological Station. XXXIV, 1928. Copenhagen 1925. pp. 33—52.
2) A. C. Johansen. The Extent of the Annual Transplantations of Plaice in the Limfjord and the Yield resulting therefrom. Ibid. pp. 53—86.
3) Aage J. C. Jensen. The Relation between the Size of the Plaice Stock and the Quantity of "First Class Plaice-Food" in certain Parts of the Limfjord. Ibid. pp. 87—98.

It is well known that for many years past the Danish Government has made an annual grant which has almost covered the entire costs of transplanting small plaice to the inner Broads of the Limfjord. Information of great interest to economist and biologist alike regarding this important State enterprise is to be found in the above three papers. From the standpoint of the Exchequer the undertaking has from the outset proved a

success, there being abundant evidence that the commercial fisheries have benefited by an amount considerably exceeding the expenses of transplantation. Albeit, it is disquieting to observe that in recent years, the net yield has been appreciably smaller than formerly. Dr. JOHANSEN advances strong evidence that this is in the main due to the fact that a very large proportion of the transplanted fish are being caught in gill-nets, pound-nets and eel-seines soon after liberation and thus before they have reached marketable size. He considers that the use of gill-nets in the planted areas and in the western part of the Livø Broad should be forbidden for the first few months after the planting has been carried out — say until the end of July.

It would appear that the relative numbers in which the young fish have been distributed over the inner broads in the past have not been ideal. It has been unprofitable to liberate so large a proportion in the Livø Broad, and much better results would be reaped by increasing the numbers allotted to Thisted and Visby. JOHANSEN suggests that if about Kr. 20,000 are available annually for the transplantation of plaice in the Limfjord, it would, in accordance with the investigations, be regarded as profitable to expend at least half of this sum on planting plaice in Thisted and Visby Broads.

A matter of some interest is whether or not the commercial fishery in Nissum Broad has suffered in consequence of the removal of some millions of young plaice yearly for transplanting purposes. Such a contention on the part of the fishermen concerned is, after all, only human, and it is to be hoped that the men will be reassured by the finding that the removal of these fish has had no injurious effect on the fishery, but, on the contrary, it has probably actually been of benefit in that a certain thinning out of the stock has been brought about, resulting in the more rapid growth of the fish left behind. Furthermore, a not inconsiderable number of the transplanted fish when they have grown will be caught in Nissum Broad on their migrating from the inner broads towards the North Sea.

The quantitative bottom investigations ("valuations") in the Limfjord, which have been carried out annually by the Biological Station over a long period, afford extensive data concerning the fluctuation in quantity of food available to the plaice in the different districts. Drs. BLEGVAD and AAGE JENSEN elect to draw a distinction between "1st class plaice-food", i.e. animals which whenever they occur are eagerly sought by the fish, and "2nd class plaice-food" i.e. animals which are only rarely eaten by the fish, and then as a rule only in localities where there is a lack of 1st class food. Such a division of food animals implies that specific selection of food items by fishes is a principle of first importance. Not all workers, however, will be prepared to agree with a general application of this method, although in the present instance where the food species included under "1st class-food" are so obviously important, no objection can be raised to the evidence advanced as to variations in amount in different parts with season or year. One of the most significant conclusions reached is that the total amount in the inner broads generally fell away most seriously from 1924 onwards until in 1927 it was far below the average

for the whole period of investigation. In spite of exhaustive studies no complete explanation seems to be forthcoming. The amount of food consumed by plaice is shown to be definitely not the cause of the decrease, nor, so far as is known, have any predacious animals among the bottom invertebrates increased in quantity to such a degree that they can be suspected of being responsible for it. One animal, however, the viviparous blenny (*Zoarces viviparus*) has in recent years spread to a surprising extent all over the Limfjord. As this fish feeds on the same animals as does the plaice, it is not unreasonable of Blegvad to suggest that the occurrence of a much greater number of Zoarces has very largely brought about the reduction of plaice-food to its present low level. He attributes this rise in numbers of Zoarces (and also of the Black Goby) to a prolonged shortage of cod which normally feed heavily upon blenny and goby, and he advocates the transplanting of young cod to the inner broads as a curative measure — the blenny would be kept down by the cod, and more food would thereby become available to the plaice. Aage Jensen on the other hand, reaches the conclusion that the total amount of first class plaice-food is comparatively unaffected by the numbers of Zoarces and gobies. Thus it would appear that unanimous opinion as to the main cause of the decreasing total quantity of plaice-food has not yet been secured.

In conclusion, it must be stated that in their supervision of these transplantations of plaice, the Danish workers are demonstrating in an able manner the economic value of continuous biological research. E. F.

W. Mielck. Die Verbreitung der Heringslarven in der Nordsee im Winter. Cons. Perm. Int. pour l'Explor. de la Mer. Rapp. et Proc.-Verb., Vol. LIV. Appendix I. Copenhague. 1929.

This paper is a preliminary report on the distribution of the herring larvae of the North Sea, and is a description of the material collected during various German cruises. As is customary, the location of larvae with yolk-sacs, and those of 8—9 mm. in length which have just absorbed their yolk-sacs, is taken as indicating the approximate positions of the spawning grounds. By this means, the known spawning grounds West of Long. 3° E. were defined, and in the comparatively unknown area East of this line a few spawning places were indicated, the small size of the larvae in January—March showing that they could not have been transported by currents from either the Dogger area or the Southern Bight. In the neighbourhood of the Jutland Bank small numbers of larvae were found in January, but these spawnings are probably of no great importance, as it is believed that the young herrings of the south-eastern North Sea, are derived from the spawning grounds W. of Long: 3° E.

Quantitatively, the bulk of the larvae were found in the Southern Bight, (377 per square metre in February), — additional evidence as to the importance of that area as a spawning ground. Cromer Knoll also was shown as a good spawning place.

Prof. Mielck divided the western region into three areas, (1) Northumberland to Norfolk, (2) SW. Dogger, (3) the Southern Bight, and he

showed how the larvae from area (1), together with additions from Scottish waters, are carried partly to area (3) and partly in an easterly or south-easterly direction. Area (3) also receives additions from the Channel and the resultant mixture of fry is carried along the West Friesian Islands into the German Bight, where the fry from the northern spawning grounds are also carried, resulting in a general mixture of larvae on the eastern side of the North Sea.

The data from Heligoland showed the occurrence of three waves of fairly large larvae between December and April, and these were thought to include some of the fry from the winter spawning of the Southern Bight.

The paper substantiates very largely the previous work of William Wallace who suggested in 1922 that there was a "split" in the distribution of the young herrings of the Southern Bight and the eastern English Channel, one part supplying the whitebait of the South-east English coast, and the other, that of the German Bight.

This fundamental work of Prof. Mielck together with that of Wallace, should prove of great value in connection with any future studies on the fluctuation of the herring fisheries of the North Sea. W. C. H.

O. Nybelin. Untersuchungen über Heringslarven im Kattegat und in der südlichen Ostsee. — Svenska Hydrogr.-Biolog. Komm. Skr. N. S. Biologi. Bd. 1. Nr. 3. Stockholm 1929.

Der durch Kurvenfiguren und Karten illustrierten Arbeit liegen Fänge zugrunde, welche im September 1926 und im Oktober 1926 und 1927 im Kattegat und in der südlichen Ostsee (im Gebiet Karlskrona—Bornholm—Kriegers Flak) gemacht wurden. Die meisten Fänge sind mit einem horizontal gezogenen Ringnetz von 2 m Ringdurchmesser, einige mit dem Scherbrutnetz und Petersen's Jungfischtrawl ausgeführt worden. Verfasser weist darauf hin, dass in dem sehr ergiebigen jedoch schwer hantierbaren Ringnetz trotz sorgfältigsten Abspülens Tiere am Stoff haften bleiben und den nächsten Fang fälschen können. Man kann aber davon ausgehen, dass alle Larven, welche unbeschädigt sind, durch den Fang erbeutet wurden, in welchem sie sich vorfanden.

Referent möchte empfehlen, für die quantitative Bestimmung der Zahl der jungen Larven Hensens Eiernetz zu benutzen, bei welchem kein Abspülverlust vorkommt. Bei den grossen Horizontalnetzen empfiehlt sich Aufhängen des Netzes zum Trocknen nach jedem Fang; die am Stoff haften gebliebenen Larven sind dann leichter als nicht zum neuen Fang gehörig zu erkennen.

Kattegat: Während die ersten Fänge (10. IX. 1926) negativ waren, wurden am 4.-6. X. stets Larven, wenn auch in verhältnismässig geringer Zahl, gefangen; Länge der Larven 6—12 mm, Frequenzmaximum bei 7 mm. Etwa drei Wochen später (22.-23. X.) waren die Larven zahlreicher; Länge 6—18 mm, Frequenzmaximum bei 10 mm. Daraus wird gefolgert, dass das Ausschlüpfen in beschränkter Zeit erfolgt, Anfang Oktober sein Maximum noch nicht erreicht hat, Ende des Monats aber beinahe abgeschlossen ist. Der durchschnittliche Zuwachs während dieser drei Wochen

kann wohl auf etwa 5 mm geschätzt werden. Keine Unterschiede in der Tiefenverteilung zwischen jüngeren und älteren Larven. Wahrscheinlich befanden sich alle Fangstationen innerhalb der Laichgebiete des Herings im Kattegat oder in deren unmittelbarer Nähe. Das 1927 erbeutete Material ist für sichere Schlussfolgerungen zu spärlich, schliesst sich aber dem von 1926 an.

Südliche Ostsee: Hier ist das gesammelte Material nicht so einheitlich wie im Kattegat, wofür vier Gründe genannt werden: Die Ostsee-Fänge wurden in einem grösseren Zeitraum gemacht; das befischte Gebiet war grösser und umfasste wahrscheinlich Laichplätze als auch Stellen ausserhalb derselben; das Laichen ist vermutlich zeitlich nicht so beschränkt wie im Kattegat und erfolgt in mehreren Perioden; endlich ist die bathymetrische Verteilung der Larven ungleichmässig, die jüngeren Stadien leben höher als die älteren, was bei ungleichmässiger Befischung von Oberfläche und Tiefe sich am Gesamtresultat geltend macht. Als Grund für die verschiedene Tiefenverteilung werden die Salzgehaltsunterschiede zwischen Oberfläche und Tiefe angenommen. Laichplätze, an welchen die meisten und jüngsten Larven gefangen wurden, liegen an der Küste bei Karlskrona, an der Küste nördlich Simrishamn — vielleicht Endpunkte eines entlang der ganzen Hanö-Bucht sich erstreckenden Laichgebietes? — und im Gebiet Westküste von Bornholm—Arcona. Das Material von 1927 zeigt dem von 1926 ganz analoge Verhältnisse. KÜNNE.

G. GILSON. La pêche littorale sur les Côtes de Belgique. Cons. Perm. Int. pour l'Explor. de la Mer. Rapp. et Proc.-Verb. Vol. LI. Copenhague. 1928.

It is but seldom that one has the pleasure of reading a report dealing with such a lengthy series of observations which, with the exception of six years due to the disturbance of the war, have been carried on since 1905 as part of the Belgian contribution to the researches carried out in accordance with the programme of the International Council. Dr. GILSON's difficulties have been great since up to the present, Belgian research workers have lacked a Marine Laboratory and adequate staff, and the work has only been made possible by the generous expenditure of time and money by Dr. GILSON himself. Happily this state of things has ended and a new era opens with the establishment, for which Dr. GILSON was largely instrumental, of the Marine Laboratory at Ostende.

A very complete picture of the Belgian coastal fishery is given, in fact the fullest account of any coastal fishery that has been written, since it deals with the samples of the weekly catches of two types of vessels over a period of some 15 to 16 years. The boats were the "Canots", or open cutters of 1—3 tons, and the "Cotres", half-decked cutters of 5—10 tons, both using the beam trawl. In addition, samples were taken during the shrimping season of the hand pushed shrimp nets. Caught by a boat of each type, samples of all the fish and for a considerable period the invertebrates also, were sorted, identified and measured. For the purposes of this report, the Plaice, Dabs and Soles have been tabulated into three categories, those of 1—15 cms., 16—24 cms., and over 24 cms.

The sale of these three species of fish below 18 cms. is prohibited in Belgium, but the regulation is not strictly enforced and most of the fish of 15 cms. and over are landed.

The figures obtained from the single boats have been raised to the total catch of the whole Belgian fleet of "Canots" and "Cotres" which show clearly the immense destruction of very small fish which is caused by these small boats and the different effect of each type on each species of fish; for example, the "Cotres" catch the greatest amount of Plaice and Dabs, and the "Canots" the most soles. A very low percentage of the fish taken are over 25 cms. and nearly half are below 16 cms. in length.

The many tables and diagrams are worthy of an intensive study since much could be deduced from them with regard to fluctuations, movements offshore and other interesting matters. The main object of the report, however, is to show how greatly the stock of the open sea fishery must suffer from the inshore depredations. With all due reserve, Dr. Gilson raises the figures obtained from the Belgian coast to the whole continental North Sea coast up to the Skagerrak and concludes that the coastal fishery cannot destroy annually less than approximately $39^1/_2$ millions of young plaice, $121^1/_2$ millions of young dabs and well over 15 millions of small soles. While these numbers are but small as compared with the destruction of young fish by the steam trawlers fishing the North Sea, yet they add over 13 per cent. to the number of plaice of under 25 cms. caught annually in the North Sea as estimated by Heincke.

Besides the destruction caused by this inshore trawling of fish, Dr. Gilson raises a question that has too often been overlooked by the advocates of the "thinning" theory, and that is the effect of continuous trawling, even by the small beam trawl, on the bottom living invertebrates which form the food of fish. The examination of the trawl contents after hauling in certain localities revealed the fact that a very great quantity of the bottom fauna are killed or mutilated, which not only reduces the amount of the benthic fish food but also consequently of planktonic food since many of the benthic forms have a planktonic larval stage. It would be interesting to know whether the relative amount of destruction of bottom fauna by the light seine net used by the Danes and the beam trawl used by other continental coastal fishermen could have any bearing on the more rapid growth rate of the plaice off the Danish coast as compared with the slow growth rate of the Dutch coast.

Dr. Gilson urges the necessity for International regulations in order to protect the young fish and presents his arguments very convincingly. He rightly concludes that the resources for recruiting the offshore stock are not inexhaustible and suggests two means of protection. Firstly, the institution of preserves for young fish where no fishing would be allowed; these areas would be chosen after a full examination by means of bottom sampling and should be where fishing was unprofitable or difficult owing to the nature of the bottom. Secondly, the institution of an International size limit of 22 cms. This he believes to be too low but the really effective limit of 25 cms. would ruin the inshore fishermen. However, he considers that it might be gradually raised later on.

The arguments against a size limit are well known, in particular that

it would not keep the boats off the young fish grounds and the fish would merely be thrown overboard dead. He is of the opinion, however, that with proper precautions by the fishermen, a considerable proportion of the fish caught by the inshore fishermen could be returned to the sea alive. There is, moreover, a recent development in the fishing industry which furnishes a powerful argument in favour of a size limit; this is the utilisation of undersized fish and wasted parts of fish for the manufacture of meal and other bye-products. While it is all to the good to turn the inedible portions of marketable fish into such products, the fact that a market for fish of any size is increasing can only be viewed with great apprehension and every effort should be made to check the expansion before it reaches unmanageable proportions.

Space will not permit one to deal with the many other points that Dr. Gilson brings forward; it must suffice when it is said that no one who is investigating the problems of the North Sea should fail to make a careful study of this most interesting report; for the first time the coastal fishery has been examined with sufficient continuity to obviate the erroneous ideas that are obtained from spasmodic sampling, where such factors as weather, shoaling, and migrations can give but a very distorted impression. D. E. T.-P.

H. M. Kyle. Die Seefischerei von Grossbritannien und Irland. Handbuch der Seefischerei Nordeuropas. Herausgegeben von H. Lübbert und E. Ehrenbaum. Band VI. Heft 1—3. Mit 1 Titelbild, 77 Abbildungen im Text und auf Tafel I—V. S. 1—169. Stuttgart 1929.

An account of the sea fisheries of northern Europe in ten volumes is being published at Stuttgart, with Mr. H. Lübbert and Professor Ehrenbaum as Editors. The sixth volume is devoted to the sea fisheries of Great Britain and Ireland by Dr. Kyle. The first three (of four) parts of this volume have just been issued under the title given above.

These three parts are concerned respectively with:—

1) An historical account of the development of British Fisheries (57 pp.).
2) Administration and regulation of the Fisheries (19 pp.).
3) Methods of Fishing and Fishing Vessels (90 pp.).

It may be said at once that this work is clear, compact, up-to-date and so far as is possible in the limited space allowed, a complete account of British sea fisheries — past and present.

No branch of the fisheries — however insignificant — is omitted and the more important sections of the fisheries are described with a wealth of detail and with abundant illustrations.

Dr. Kyle deals first with the historical account under four separate headings. From the commencement to the sixteenth century, from 1600 to 1800, from 1800 to 1900 and finally from 1900 to 1925.

The main aspects of this important and interesting branch of the sea fisheries are adequately dealt with.

Dr. Kyle traces the development of the British sea fisheries from

its earliest commencement. The prehistoric fisheries, which ultimately developed into a settled herring fishery at Yarmouth, are first described.

A detailed account of the early herring fishery follows. Dr. KYLE, in the section devoted to the fisheries prior to 1600, quotes interesting documentary material, the result of careful research into a bye-path of history.

The growth of the herring fisheries in the seventeenth and eighteenth centuries is fully described, the period of the Royal Fishery Societies of the Stuarts and the later Bounty Systems both being adequately treated. The section dealing with the early whale fisheries is not so full, although these whaling cruises were a training for deep-sea fishermen.

Even of recent years the longest trawling voyages originated in the east coast ports such as Hull which have long had a tradition of distant fishing voyages.

The last portion of the historical section deals with the modern development of the great drift-net and trawl fisheries. The reports of the various Committees and Commissions appointed to inquire into the alleged destructiveness of trawling are summarised. The vexed question of the closure of the Moray Firth is dealt with historically. Dr. KYLE is very severe on artificial hatching of sea fish.

Part two deals with administration. Here again Dr. KYLE gives an adequate account. In the section dealing with the administration of the English fisheries, Dr. KYLE enters the field of criticism. He points out certain lacunæ in the reports of the Central Department (p. 66) and certain anomalies in the division of administrative duties between the Central Department and the local authorities, the Local Sea Fisheries Committees (p. 68). It must not be forgotten that the Central Department probably has a good reply to these criticisms.

This section contains the best and most concise account of administration of the British sea fisheries that has hitherto been published. Practically nothing of any importance has been omitted. There is also an interesting account of the activities of the Worshipful Company of Fishmongers of London, a Company which still has an active interest in the trade from which it originated.

In the third section, dealing with Fishing Vessels, and methods of fishing, Dr. KYLE is on less contentious ground. His account is concise and adequate and anyone reading the section cannot fail to have a clear conception of the present condition of the British sea fisheries, which are still the most important in northern Europe. There are four sections dealing respectively with the trawl fisheries, the drift-net fisheries, other deep-sea fisheries including line-fishing and whaling; and finally the coastal fisheries, the Cinderella of the sea fisheries, at any rate in England and Wales.

This section of the work is particularly well-illustrated, no important branch of the fisheries being without illustrative diagrams, which makes the practical side readily intelligible to a layman.

There are, in particular, full descriptions, with illustrative diagrams of the modern steam trawler, with its nets and gear. For over fifty years trawling has been the most important branch of the English sea fisheries,

but in Scotland the drift-net fishery for herring gives the greatest quantity of fish.

Taking England and Scotland together we find that the percentage yield of the fisheries is as follows:— Trawl, 50; Drift-net, 42; Long-lines, 5; and other methods, 3 per cent.

The drift-net is also described in detail and with ample illustrations.

One of the most interesting sections of the book is that which deals with modern whaling so far as it is carried on from the British Isles. It will surprise many people to learn that in British waters as many as 730 whales have been killed in a single year and that the whaling steamers have averaged 70 whales each in a season. At the present time there are only two whaling companies operating in British waters, one from the Hebrides and one from the Shetlands.

Finally the publication of this work reflects the greatest credit on all concerned.

It is certainly strange that one has to turn to a work in a foreign language and published abroad for the best and most up-to-date account of the British sea fisheries. Apparently the publication of works of this sort is not lightly to be undertaken in Great Britain. J. T. J.

H. M. Kyle. Die Fischerei von Grossbritannien und Irland. Handbuch der Seefischerei Nordeuropas. Herausgegeben von H. Lübbert und E. Ehrenbaum. Band VI. Heft 4. Fischereidistrikte und Fischereihafen S. 171—334. Mit 110 Abbildungen im Text und 21 Tafeln. Stuttgart 1929.

This is the fourth and last part of Dr. Kyle's book on the sea fisheries of Great Britain and Ireland, the complete work forming the sixth volume of Lübbert and Ehrenbaum's Handbuch of the sea fisheries of northern Europe. This part gives a detailed description, with many illustrations and plates, of the various fishery districts and harbours of England, Scotland and Ireland.

Dr. Kyle starts with Scotland, to which one chapter, divided into twenty-one sections, is devoted.

A full description of each of the Scottish sea fisheries districts is given with a short description of the fisheries of each area, statistical tables, plans of the more important fishery harbours and many illustrations, some of which are really excellent, and quite the best of their kind we have seen anywhere. No one can read this section and fail to have an accurate idea of the present state of the Scottish sea fisheries. The description of the growth of the Shetland herring fishery is of considerable interest because it was off the Shetlands that the bounty system vessels were required to operate, a fishery from which the great British sea fisheries have originated. The changes that are taking place in the Scottish sea fisheries are carefully noted. In some instances these changes are of a striking nature, for instance, in the ports of the Moray Firth the large sailing boats have diminished from nearly 1800 at the commencement of this century to 8 in 1926. In Aberdeen the weight of trawl caught fish landed in 1889 was 137,193 cwts value £98,652; in 1926 it was 2,142,306 cwts value £1,743,121.

In the latter year the Aberdeen fishery fleet consisted of 326 vessels of 20,891 tons.

The next chapter (eleven) deals with the east coast of England. Here again we have a painstaking and accurate description of the fisheries, both inshore and deep sea, of the east coast of England. After describing the coastal fisheries of Northumberland, Dr. KYLE gives a detailed and appreciative account of the great trawl fisheries of Hull and Grimsby. It is impossible to summarise what is, on account of the limitations of space, itself really a summary. It is safe to say that there is no fishery port in Great Britain or Ireland, no matter how insignificant, which does not receive adequate treatment at Dr. KYLE's hands. The larger ports are treated with the wealth of detail which they deserve. Take Fleetwood as an example. We have a good account of the origin of the place as a fishery port, an excellent account of its present stage of development. Plans and photographs of the harbour and the arrangements for coaling and icing the steam trawlers and the discharges, sale and dispatch of the fish to the inland markets. Finally a short appreciative account of Fleetwood's probable future. All of this is condensed in a truly remarkable way. Not a word is wasted. It would be difficult to find elsewhere a detailed account of the British Sea Fishery Districts and the British Sea-fishing Harbours included within the limits of such a modest volume.

The publication of this volume reflects the greatest credit on all concerned and in particular on the courage of the publishers. (E. SCHWEIZERBART'sche Verlagsbuchhandlung). We wonder what any English firm of publishers would say to a proposal to publish a work on European sea fisheries in ten volumes. The proposer would probably be subjected to a medical test for sanity. J. T. J.

JOHN VAN OOSTEN. Life History of the Lake Herring (*Leucichthys artedi* Le Sueur) of Lake Huron as revealed by its Scales, with a Critique of the Scale Method. U. S. Dep. Commerce. Bull. Bureau of Fisheries, XLIV, 1928. Doc. No. 1053. pp. 265—428. Washington 1929.

This valuable paper is of interest to others than the students of the Coregonids, if only for its bibliography of nearly two hundred references. It is of particular interest to the reviewer because Dr. VAN OOSTEN has also felt the necessity of a comprehensive review of age-determination methods, a necessity that caused the reviewer to undertake a similar enquiry in connection with the investigations of codling in the North Sea[1]). It must be acknowledged that Dr. VAN OOSTEN introduces some important North American papers which the reviewer failed to notice in his survey of the literature, and at the same time certain important papers published in Europe have not apparently reached the American libraries to which Dr. VAN OOSTEN had access. For the complete omission of the Russian work he may perhaps be forgiven, for it is only a chance fortune of the late war that makes these available to us at Lowestoft, but failure to notice WALLACE's work on the plaice otolith is less excusable, for that

[1]) Fishery Investigations II. XI. 3. London, 1929.

work placed Reibisch's method on a firm basis which had stood the test of careful and extensive criticism, a position held by no other age-determination technique until the long series of Lea's investigations established the Norwegian herring scale method in the same elevation.

Apart from the intrinsic value of Dr. Van Oosten's historical review, he makes some interesting commentaries. For example, on pp. 292—293, he summarises the indirect evidence of the validity of the scale method under ten heads, and points out that in spite of the criticisms, which he has already listed, the data of nine of these lines of indirect evidence have passed unchallenged. This, in itself, is enough to convince us of the general truth of the scale theory. In dealing with the direct or experimental evidence of the validity of the scale method it is gratifying to find him agreeing with Schneider and the reviewer in emphasising the importance of Walter's (1901) paper on the carp. He cites more papers on the direct evidence than had come to the notice of the reviewer, and observes that so far as they go, the large majority of the experiments favour the validity of the theory. He also observes, however, as did the reviewer in connection with the codling work, that much of this evidence depends on interpretation of the scales in the light of known knowledge of the history of the specimens. He pertinently refers to Hintze's pioneer work on the carp scale, where an interpretation which has since been shown by Walter to be wrong and not conformable with Hoffbauer's method, was apparently justified by knowledge of the history of the specimens.

Dr. Van Oosten goes on to an able description of the history of the method of calculating body length from the growth of the scale. We may summarise this in his own words (p. 310):—

"From this review, it is apparent that the question of the validity of growth calculations based on the scales of fishes is a thorny one, indeed . . . There is also much disagreement as to the causes underlying the discrepancies in computed growth values and as to the efficacy of the various methods employed to eliminate these errors; and yet, peculiarly enough, all the experimental evidences reviewed above show, as far as they go, that calculated and empirical growth measurements agree almost exactly". This seems a fair summary of the situation to-day. That is to say, for some material Lea's linear relation of scale and body length with a common origin gives correct results, in other material corrections are necessary, different corrections according to the material. In Van Oosten's *Leucicthys* material he uses Lea's simple method, and suggests that no correction for late scale-formation is necessary, because this is compensated by the scale growing at first more quickly than the body. One may perhaps usefully recall that in Lea's and Hodgson's herring scales, where such striking agreement between calculated and empirical l_1s has been recorded, the scales were taken from one particular part of the body, for which Lea's researches had shewn that this simple relation held. One may hazard the opinion that the multifarious nature of the corrections introduced by other workers is due to less precision in selection of scales from a particular area of the body, for the scales do not appear simultaneously on the whole body and must therefore have different growth-

rates relatively to the body in order to produce the complete scale covering. VAN OOSTEN himself used scales from a selected area on the body.

In only one respect would the reviewer join issue with the writer of the paper, namely with regard to the occurrence of a small proportion of misleading scales. Figs. 8, 9, 10 are three of the very beautiful scale photographs illustrating this paper. They are photographs of three scales from the same fish. In the first scale four annuli (commonly called "winter rings") are clearly marked. In the second scale the first ring is less clear and in the third there is no trace of it. Nevertheless, Dr. VAN OOSTEN is content that so long as a few scales are examined from each fish the correct age will be read. This is no doubt true for the majority of specimens. But, if we allow variation of structure as a universal attribute of organisms, it seems clear that if a few scales may be misleading in some fish, there will be others in which the misleading scales will be many and some few fish indeed in which misleading scales will outnumber correctly-reading scales. This conclusion is consonant with a critical study of the literature, and it may be suggested that Dr. VAN OOSTEN did not reach it because his own material provided no possible line of criticism of the scale method of age-determination except in regard to the majority of his fish. Indeed in the *Leucichthys* of Lake Huron, which is subjected to the severity of a North American continental winter and which spawns in November, it is probable that there are but few misleading scales.

Dr. VAN OOSTEN adopts the best technique for applying the scale method to his material after very careful enquiries. He prefers to use "diameter" measurements of the scale rather than the usual "radius" measures, since thereby he obtains less variation in the ratio of scale to body, and the computed lengths so obtained are higher, and therefore nearer the empirical lengths in the younger groups. He observes LEA's phenomenon of "apparent change in growth-rate". By first restricting the discussion to that of scale measurements alone, and not the computed lengths obtained from the measurements, he is able to show that the phenomenon is manifested on the scales themselves, (but aggravated in the calculation) and is partly to be explained, as LEA has explained it in other material, by the selection brought about by sexual maturity — the larger fish of an age-group becoming mature before the smaller. But the increase of computed lengths in the very old fish is only to be explained as an example of GILBERT'S (1914) "law of compensation of growth". The ratio of head to body length is of no importance. These and other technical conclusions are supported by weighty evidence.

We are not directly concerned with the results of the applications of the method to the "lake herring" of Lake Huron; but what is remarkable is the number of conclusions to be reached by application of this technique. The most interesting result perhaps is this: VAN OOSTEN, by a very careful analysis of his data, decided that the years 1915 –1918 were characterised by a low growth-rate in the "herring" of Saginaw Bay. This was synchronous with wartime pollution of the Saginaw River from a chemical factory, and to this pollution the low growth-rate is therefore ascribed. From the growth calculations of the scales the financial loss to the fishermen caused by the pollution reducing the growth-rate, is estimated at more than one hundred thousand dollars.

We may note in passing that the five species of *Leucicthys* recognised by JORDAN and EVERMANN in Lake Huron are now all referred to the one considered here.

One error may be noted. In the text p. 324 we are led to believe that Table 17 is a summary or rearrangement of the data of Table 16. But by addition of the constituent samples we find that Table 16 includes 1286 specimens and Table 17 includes 1697 specimens.

One may congratulate the author on the care with which he has brought his laborious study to such satisfactory conclusions.

MICHAEL GRAHAM.

Current Bibliography.

Prepared by the Editor with the assistance of Miss THURSBY-PELHAM.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in the North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

The classification of entries follows in a general way that adopted in Dr. ALLEN's Selected Bibliography published in Vol. I, Nos. 1 and 2 of the Journal, and since reprinted.

Subscribers and those on the distribution list will receive regularly upon application to the Administrative Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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